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Understanding the relationships between microbial contamination, food safety and food security

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
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By
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Abstract of a thesis submitted in partial fulfilment of the requirements for the
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The majority of foodborne outbreaks in recent years have been linked to microbial contamination of food products. These food outbreaks are capable of causing considerable food losses and, hence, could play a role in global food insecurity. This research discusses the importance of microbial food safety in the supply chain to reduce the possibility of contamination. Microbial contamination may take place in one or more of the three major stages within the food supply chain: pre-farming, farming or post-farming. *Campylobacter*, *Salmonella*, *Listeria monocytogenes*, *E. coli* O157:H7 and non-O157:H7 STEC *E. coli* are the most common pathogenic bacteria associated with food safety issues in the food supply chain. Efficient processes of control and effective food safety management systems are vital elements for reducing microbial contamination and improving food security.

Foodborne illnesses can generate considerable economic losses for any country, and it has been estimated in Australia and New Zealand at US\$1.289 billion and \$86 million, respectively, per year. Food products such as meat and milk contribute highly to the New Zealand economy and constitute about 60% of total exports. Thus, there is a demand for developing food safety programmes to protect both the New Zealand economy and also consumers' health.

The considerable time given to the food loss and waste topic is for several reasons, including the issue of food insecurity and famine. The fact is that the world population is increasing and is set to reach more than 9 billion by 2050 and this growth will require at least 70% more in food production. Studies on edible food waste have stated that waste food can have an impact on improving food security and opening a window of opportunity to feed more people. On the one hand, information about food waste will help in the development of new practices to decrease waste. On the other hand, the severe impact of microbial food outbreaks on society is increasing the motivation to study the estimated costs to the community of these outbreaks resulting from foodborne illnesses.

In this context, my study will focus on: (i) the local and international impact of a food scare that occurred in August 2013 on New Zealand's economic well-being; (ii) collecting data for food microbe-associated international outbreaks between 2011-2015 and correlating this with food safety and security; and (iii) examining the amount and sources of food waste produced by New Zealand households, takeaway shops and restaurants in the Canterbury region, and identifying possible recommendations to improve food security through food safety management.

It is fact that different hazards occur at different stages of the supply chain and may result in a food scare or foodborne outbreak. This situation could negatively influence the food security. Observations made in this study suggested that operations involved at different stages of the food supply need effective food safety systems to minimize contamination risk and food loss.

Keywords: Microbial contamination, food safety, food security, food waste, economic loss

List of Publications

Peer-reviewed papers:

1. Elkhishin, M., and Hussain, M.A. Microbial safety of foods in supply chains and food security (Food safety and Security)**Submitted**

Conference abstracts:

1. Elkhishin, M., Gooneratne, R. and Hussain, M.A. (2015) Review: Microbial safety of foods in supply chain and food security. International Journal of Food Science and Technology Conference 2015, held on February 17-19, 2015 at Lincoln University, New Zealand.....**Poster presentation**
2. Elkhishin, M., Gooneratne, R. and Hussain, M.A. (2015) Relationship between microbial contamination and food safety and food security. NZMS conference, 2015 held on 2-5 November, 2015 in Rotorua, New Zealand.....**Oral presentation**

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List of Symbols and Abbreviations

Microorganisms

Escherchia coli

E. coli

Escherchia coli O157:H7

E. coli O157:H7

Staphylococcus aureus

S. aureus

Staphylococcus epidermidis

S. epidermidis

Listeria monocytogenes

L. monocytogenes

Clostridium botulinum

C. botulinum

Clostridium sporogenes

C. sporogenes

General

FSC

The food supply chain

CDC

Centre for Disease Control in the USA

COI

Cost-of-illness

USDA

United States Department of Agriculture

WHO

The World Health Organisation

FAO

Food and Agriculture Organization of United Nations

GAP

Good Agricultural Practices

WPC 80

Whey protein concentrate obtained from fresh sweet whey and spray dried to 80% protein

GDP

Gross domestic product

Rework

Correcting of defects after inspection

MPI

Ministry of primary industry

Chapter 1

Introduction

The difference between the terms 'food safety' and 'food security' is often misunderstood. They are separate issues but are, nevertheless, closely inter-related. The definition of food safety is the inverse of food risk and is the probability of not facing health problems after consuming a specific food (Lawley et al 2012; Henson et al. 1993). Food security is defined as the product of availability, access, and stability of nutritious food for all people to maintain a healthy and active life (FAO, 2004). It is a term that can be used when all consumers have access to sufficient and safe food at all times. Food security is a complex issue that is affected by multiple factors, including microbial food contamination, government policies, drought, global and national market fluctuations, and population growth (Fig. 1.1). The importance of microbiological food safety is paramount because of the potential for harmful microorganisms to grow/multiply in food commodities from very low numbers to billions (Kuo and Chen 2010). Entry of possible unwanted elements in food, such as microbiological agents, are a threat to the safety of food products. This can cause an increase in foodborne outbreaks because of food poisoning and a decrease in food availability because of discarding the contaminated food products (Havelaar et al. 2010). This situation has encouraged governmental organisations to introduce more rigorous policies to decrease the risk of food contamination and, thereby, ensure the supply of safe food (Zhou and Jin 2009; Broughton and Walker 2010). Drought can, also, significantly affect the sustainability of irrigation water use for agriculture and cause food crop failures (Magan et al. 2011; Liu et al. 2013). The aforementioned factors that affect food availability and food access can result in changes in global commodity prices and cause food market fluctuations (Brown et al. 2013). This can bring about significant negative impacts on the ability of the poor to secure sufficient food supplies.

Recent studies have shown that the gaps between the current global population and food production, as well as the difference between food supply and demand, are widening (Savary et al. 2014; Grafton et al. 2015). Understanding the relationships between microbial contamination, food safety and food security, and how they can affect the global food supply would, in turn, help to highlight areas in the food supply chain (FSC) that require more attention to improve food security (Fig 1.2). For the purpose of this study, the term of food safety will refer to microbial contamination issues during and after food production, and food insecurity as food losses and foodborne incident problems.

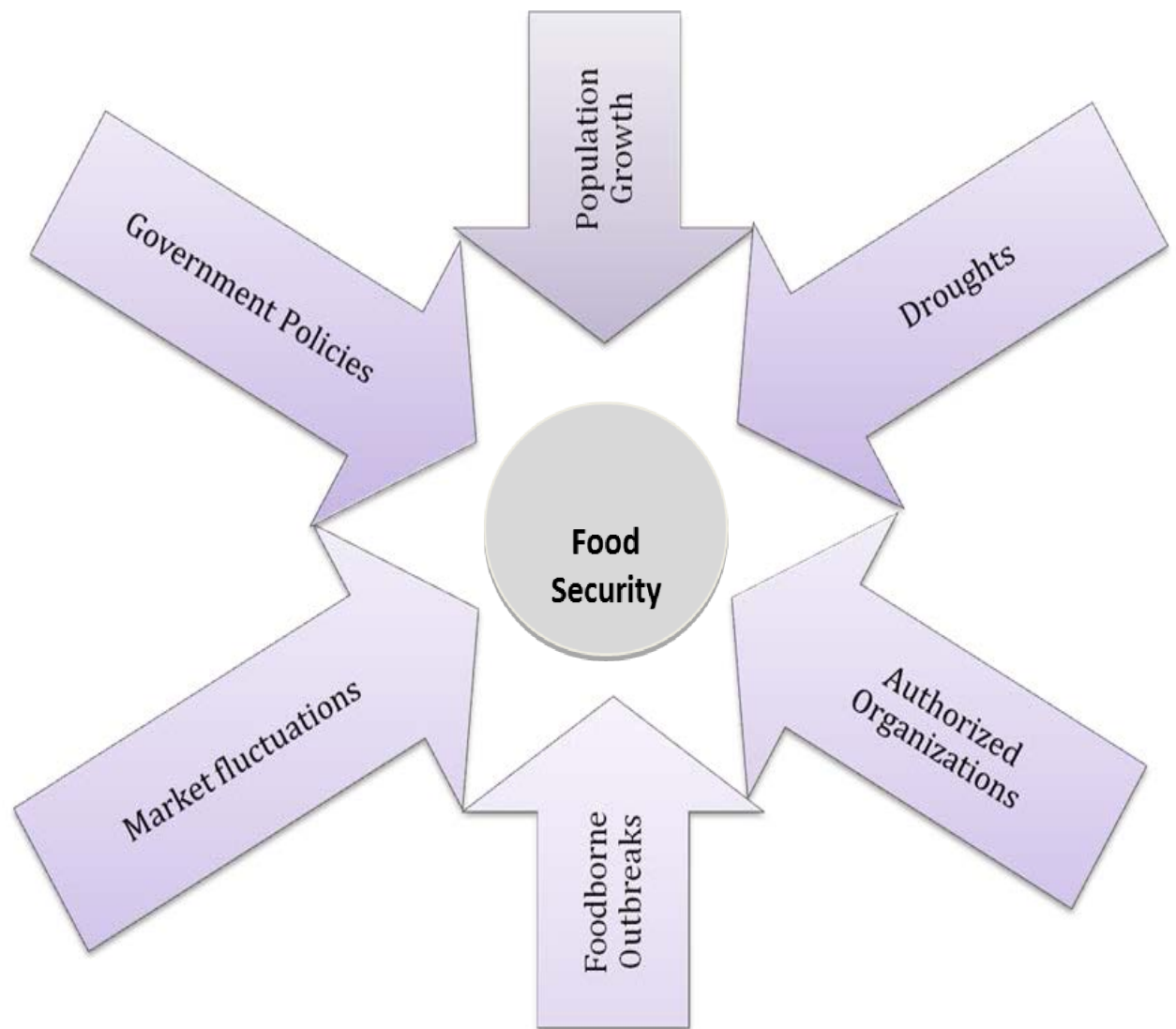


Fig.1. 1. Factors that influence food security directly or indirectly

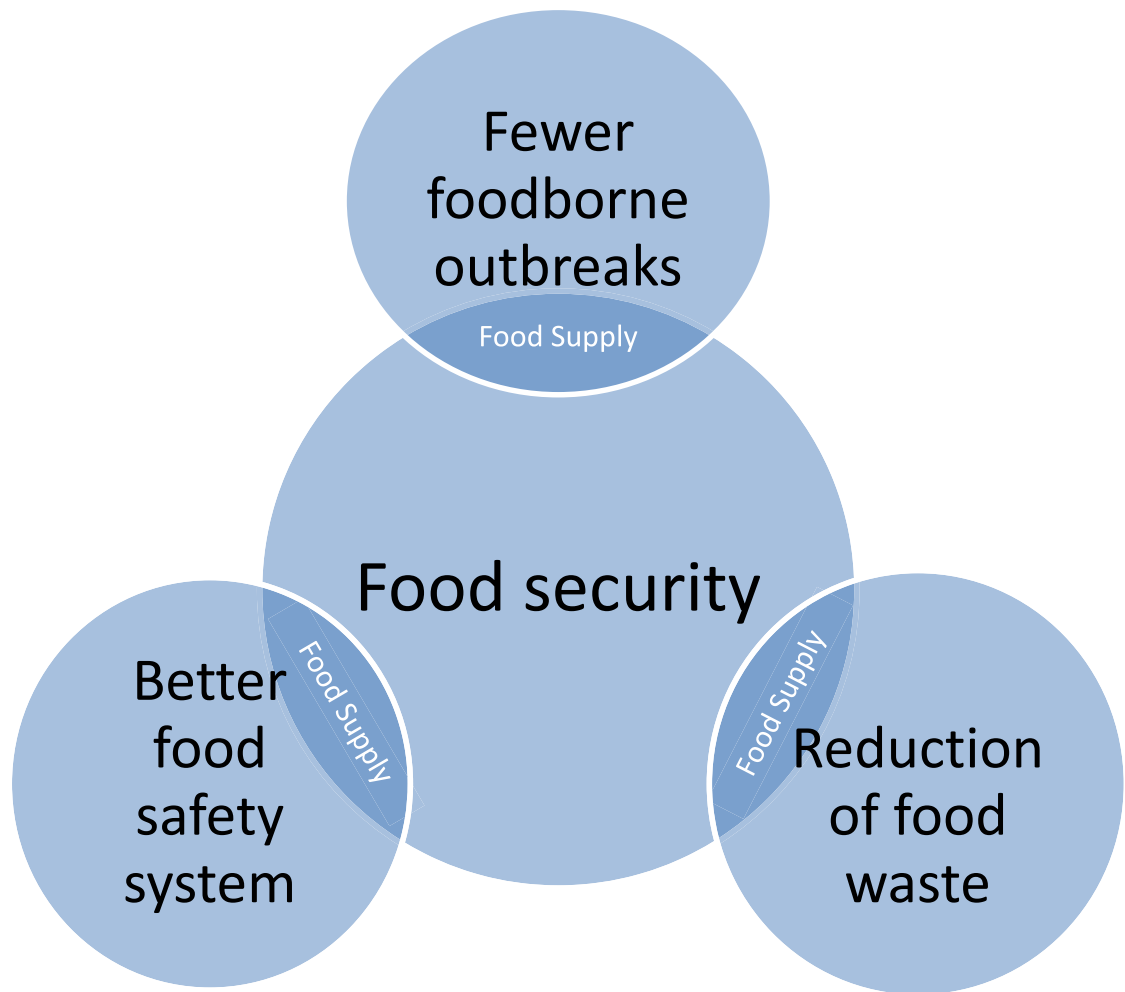


Fig.1. 2. Factors that enhance food security

1.1 Methodological Approach

This project looks at innovative ways of assessing food security through food safety issues. A schematic presentation is given in Fig 1. 3.

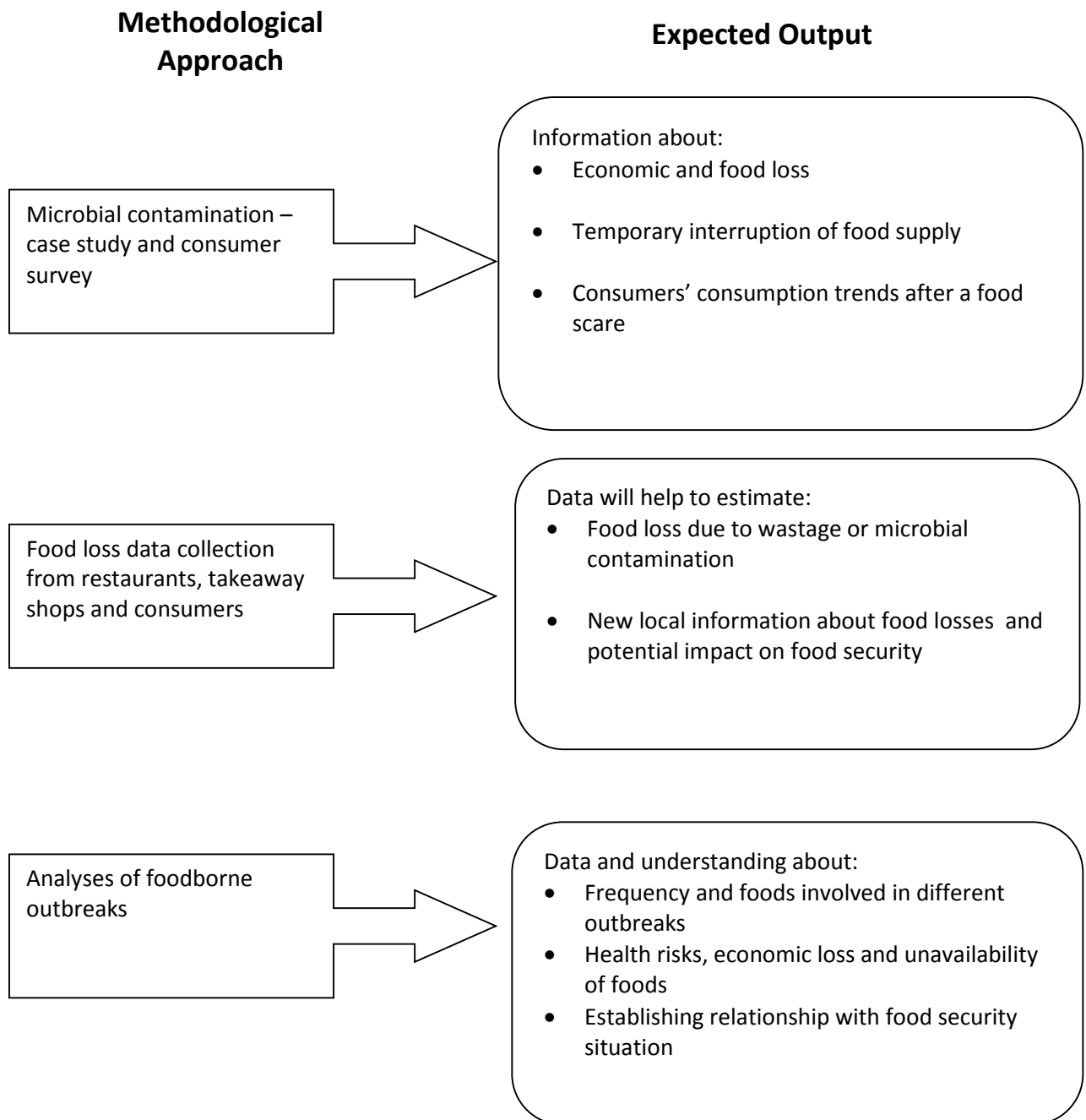


Fig.1. 3. Methodological approach and expected outcomes to establish a relationship between food safety and security

1.2 Objectives of the study

There is need for food safety research in the food supply chain to identify viable solutions for food security. This study aims to:

- 1- Understand the effect of a food scare caused by a microbial contamination incident on economic loss and food security on the basis of a case study.
- 2- Examine the amount of edible food waste generated by a number of selected households, restaurants, takeaway shops to obtain limited, but new, information about food losses due to wastage or microbial contamination in the Canterbury region.
- 3- Use available information on foodborne outbreaks in different regions around the world to explain the potential impact on food security.
- 4- Recommend solutions for improved food security through improved food safety practices.

1.3 Significance of the study

The threat of food insecurity is real and many approaches are being suggested to tackle this challenge.

Improved microbial food safety would help to increase food available for consumption. The current study will identify:

- 1- The relationship between microbial contamination in the FSC, food safety and food security.
- 2- The impact of the Fonterra food scare in New Zealand on the domestic and international markets. Also, the effect of such food scares on the consumption rate of the company's products.
- 3- The major global microbial bacteria leading to foodborne outbreaks and the number of foodborne illnesses associated with selected bacteria between 2011 and 2013.
- 4- An understanding of the amount and types of avoidable food waste in selected Canterbury households, takeaway outlets and restaurants.

Chapter 2

Literature Review

2.1 Food losses and waste in the food supply chain

According to the FAO (2013), the world produces enough food to feed everyone living on earth. However, each year, almost one out of every four calories produced to feed people was not consumed and about one third of total food products (1.3 billion tons) were either lost or wasted during production in the FSC. The FSC has been defined as “the total supply process from agricultural production, harvest or slaughter, through primary production and/or manufacturing to storage and distribution to retail sale or use in catering and by consumers” (Kuo et al. 2010). It is designed to positively influence quality, safety, sustainability, logistics and efficiency of food production and processing from the farm to the fork (Manzini et al. 2013). Food losses and waste can take place at any stage of the FSC, e.g. agricultural production, post-harvest, processing, distribution and consumption (Fig. 2.1). The term food loss most commonly refers to food products that are intended for human consumption but have, instead, been lost in production, storage, transport and processing, due to reasons such as microbial contamination (Uyttendaele et al. 2006; Montanari 2008; Kummu et al. 2012). Food waste occurs at the end of the FSC within the retail and final consumption phase and it refers to edible food products that have been discarded, degraded and not consumed by humans (Bond et al. 2013).

A report by the FAO (2011) showed that per capita food loss in North America and Oceania is about 180 kg/year and, in South/Southeast Asia, 110 kg/year (Fig. 2.2). Per capita food wasted by consumers in North-America and Europe is 100 and 115 kg/year, respectively. Food losses and waste in industrialized western countries (e.g. Europe and North-America) are slightly greater than in developing countries (e.g. sub-Saharan Africa and South/Southeast Asia) (Fig.2.2). In developing countries most of the food is lost during the food production stage and before it reaches the consumer while, in industrialized countries, more than 40% of the food is wasted unnecessarily at the consumer level.

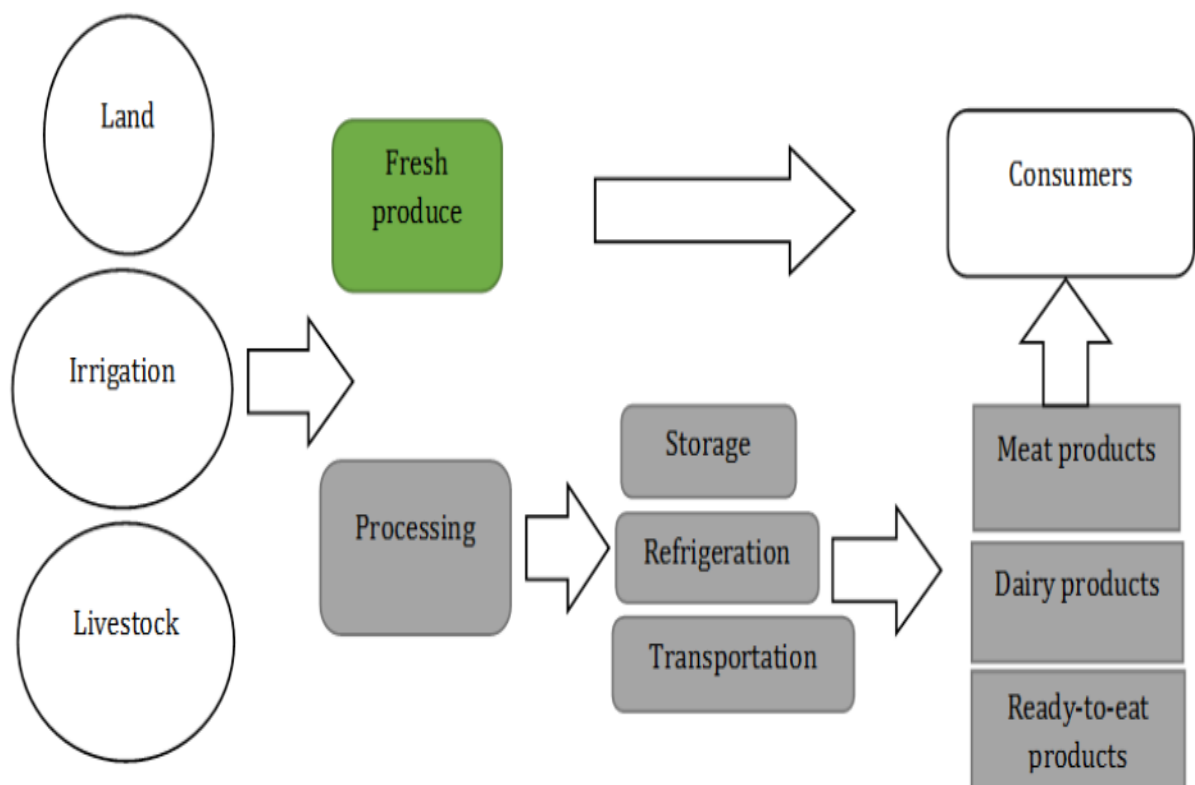


Fig.2. 1. Major stages in the food supply chain where microbial contamination was likely to occur

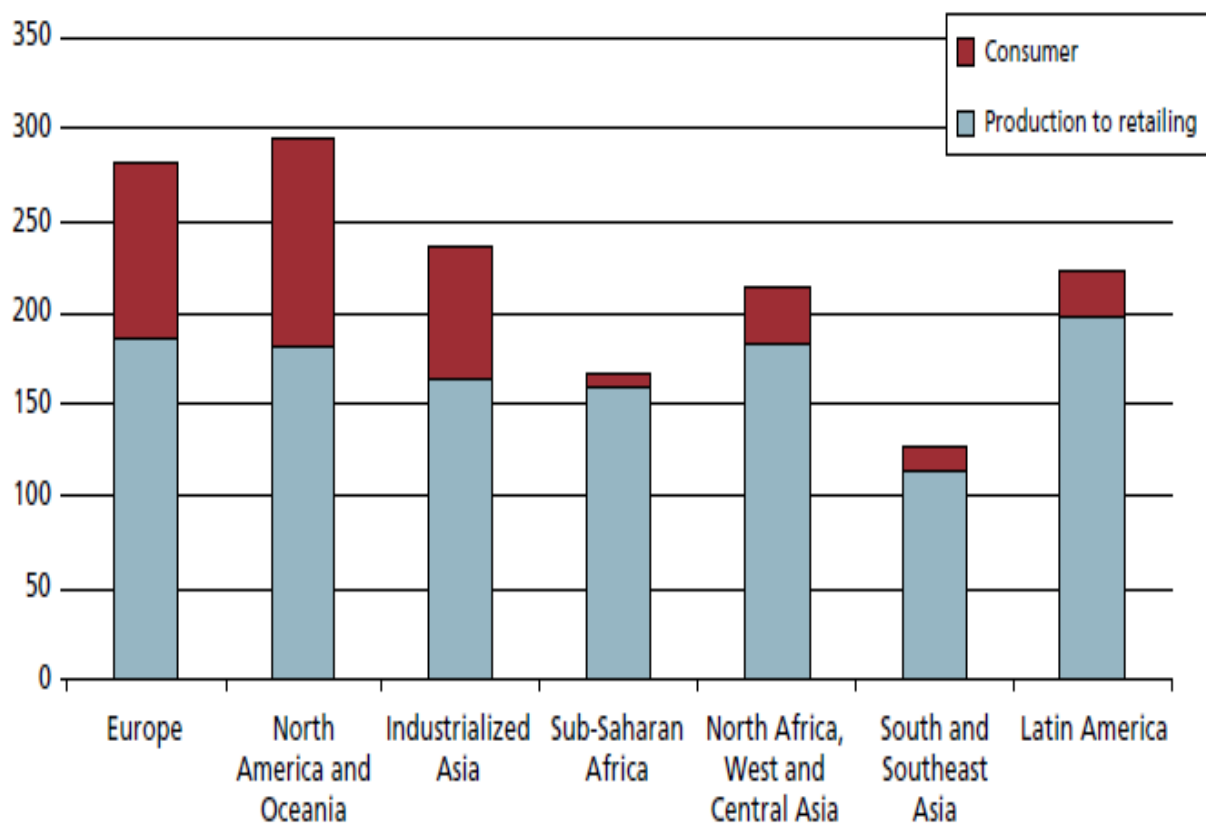


Fig. 2.2. Per capita food losses and waste at the food supply chain stages for different regions (FAO, 2011)

For most countries, food losses and waste of fruit and vegetables are higher than for other products, such as dairy and meat (Gustavsson et al. 2011; Gustavsson et al. 2013; Buzby et al. 2012; Kantor et al. 1997). Liu et al. (2013) reported that fruits and vegetables suffered losses of up to 20% to 30% compared to meat and aquatic products (with lower than a 15% loss) in the FSC in China. Insufficient refrigeration facilities in the FSC, particularly during transportation, were noted as a major factor in these losses. Better FSC management in developed countries played an important role in the reduction of food losses, particularly in low-income countries where food losses were highest. It is widely accepted that an improvement in food safety decreases the potential microbial risks and operational costs and, therefore, is vital in reducing both food losses and foodborne outbreaks to enhance food security.

Several authors demonstrated that food may become contaminated with a range of microorganisms during harvesting, processing, handling operations as a result of the behaviour of retailers and consumers (Kummu et al. 2012; Eriksson et al. 2012; Uyttendaele et al. 2006). It is not well-documented how much food loss or wastage is caused by microbial contamination each year. However, information on the cost of foodborne illnesses caused by microbial pathogens can be used as an indicator to evaluate the extent of the contamination problem. For example, organisations such as the Centre for Disease Control (CDC) in the USA, provide details about the 48 million Americans who suffer from foodborne illnesses associated with identified microbial contaminants annually (Scharff 2012). Buzby et al. (2009) estimated that 70% of diarrhoeal diseases are foodborne. Microbial pathogens are associated with a large number of foodborne outbreaks and can cause food losses. Hence, it is important to understand the common microbiological hazards in foods.

2.2 Common microbiological hazards in foods

Food security is not only paying attention to reasons behind the reductions in the food supply but also addressing issues that cause food contamination and foodborne outbreaks that indirectly contribute to food losses. A foodborne outbreak is generally defined as an incident when two or more people became sick as a result of consuming a common food or meal (Greig et al. 2009). The symptoms and severity of food poisoning varies, depending on the nature of the hazard (i.e. biological, chemical or physical agents) and its ability to cause adverse health effects. Pathogenic bacteria are the most common cause of foodborne outbreaks and food scares around the world. More than 50% of foodborne outbreaks in the USA have been linked to bacterial infections (Van Doren et al. 2013; Newell et al. 2010). However, microbial food contamination in the FSC that causes food losses and foodborne illnesses can also result in heavy economic losses. Many studies have used cost-of-illness (COI) to estimate the economic burden of an illness on a society (Scharff 2012; Lake et al. 2010; Buzby and Roberts 2009). Such studies were also useful for making sound policy decisions about food safety interventions (McLinden 2013; Traill and Koenig 2010).

Lake et al. (2010) used COI to estimate the burden of disease for certain potentially foodborne diseases (e.g. campylobacteriosis, salmonellosis, listeriosis) and their sequelae in New Zealand. The cost of foodborne infections in New Zealand is considerable and has been estimated at \$86 million per year, with approximately 90% due to campylobacteriosis. In Sweden, the estimated cost of foodborne illnesses is about \$171 million per year (McLinden et al. 2014). The Economic Research Service of the United States Department of Agriculture (USDA) reported that, in the United States of America (USA), five foodborne pathogens (*Campylobacter*, *Salmonella*, *L. monocytogenes*, *E. coli* O157:H7 and *E.coli* non-O157:H7 STEC) cost \$6.9 billion each year (Hoffmann et al. 2012). Examples of a number of bacterial foodborne outbreaks are shown in Table 2.1. International organisations such as the FAO and the World Health Organisation (WHO) have accepted the challenge to work together in order to initiate risk assessment studies of a number of pathogens in food commodities in order to protect consumers' health and economic situation (WHO 1995). Some of the most prevalent pathogens are discussed below.

Salmonella spp. are one of the leading causes of foodborne outbreaks and foodborne illnesses are a serious threat to public health worldwide. In the USA the annual estimated economic loss was \$2.4 billion in 2014 due to foodborne *Salmonella* infections (Golan, 2014). *Salmonella* spp. are commonly associated with foods of animal origin (e.g. red meat, chicken and pork). The most common symptoms of salmonellosis are abdominal cramps, diarrhoea and fever (Mead et al. 1999). Contamination by *Salmonella* can happen during processing and inappropriate food handling during manufacturing. Data from foodborne outbreaks in the USA indicate that *Salmonella* infections were responsible for 18% of foodborne diseases in 2006 (Painter et al. 2013), but increased to 35% in 2011 (CDC 2011) and 38% in 2013 (CDC 2013). In New Zealand *Salmonella* spp., were responsible for 6.6% of foodborne outbreaks in 2011 (ESR 2011) and increased to 10% in 2012 (ESR 2012). Despite the improvements to food safety standards in the FSC, *Salmonella* infections have continued to increase and cause considerable losses to global food safety through productivity/production losses and recalls.

Campylobacter spp. cause serious bacterial food poisoning. In the USA, campylobacter is responsible for more than 600,000 illnesses that cost over \$1.3 billion each year (Wesley and Muraoka 2011). Approximately, 50% of these illnesses were attributed to poultry products, such as chicken burgers and nuggets (Smith 2013). In the Netherlands, the Campylobacter Risk Management and Assessment (CARMA) estimated the cost of campylobacteriosis at 21 million euros annually, with 20 to 40% of cases attributed to contaminated poultry (Tariq and Havelaar 2011). These bacteria infect about 1% of the population of Western Europe and are caused by inappropriate handling of contaminated food (Humphrey et al. 2007, Uyttendaele et al. 2006). In New Zealand, campylobacteriosis has been a notifiable disease in New Zealand since 1980 (Sears et al. 2011). The Institute of Environmental Science and Research Ltd (ESR) reported that *Campylobacter* spp. were the most commonly identified agents

in poultry and dairy outbreaks in 2013 and caused 13.3% of the total reported foodborne disease outbreaks (ESR 2014). The economic loss due to a *Campylobacter* outbreak in August 2012 was estimated at \$1.184 million (Sheerin et al. 2013). Most research has shown that improved farm biosecurity and consumer awareness may reduce the prevalence of these infections in livestock and humans (Fraser et al. 2010; El-Shibiny et al. 2009; Rosenquist et al. 2009).

Some *E. coli* strains are pathogens and flourish in the gut of many host species. *E. coli* O157:H7 was identified in 1982 and is now recognized as a dangerous foodborne pathogen. This, and the foodborne Shiga toxin-producing *E. coli* (STEC), have been implicated in many outbreaks around the world and the illnesses costs about \$280 million annually in the USA (Hoffmann et al. 2012). The annual foodborne outbreaks reported by CDC (2014) attributed STEC to 29 confirmed outbreaks in the USA in 2013, mostly caused by fresh produce (raw fruits and vegetables). These strains were also reportedly responsible for an outbreak in the UK in 2007 that caused 157 hospitalized cases and one death (Jay et al. 2007). In Germany, in 2011, approximately 941 people were infected with *E. coli* O104:H4 (Rasko et al. 2011) from food. In New Zealand, STEC has caused two outbreaks and 11 illnesses were reported by ESR (2013). In the case of *E. coli* O157:H7, most of the infections were from beef and minced meat (Newell et al. 2010).

Table. 2.1 Examples of foodborne outbreaks in 2013 and 2014 caused by pathogenic bacteria

Foodborne Outbreak	Pathogenic bacteria	Region/ Country	Initial announcement	Causalities	Estimated economic loss	Reference
Bean sprouts	<i>Salmonella</i>	USA	November, 2014	115 people infected, twenty-five percent of ill persons hospitalized	Destruction by Wonton Foods Inc. of contaminated bean sprouts and any remaining products	CDC 2014
Foster Farms chicken	<i>Salmonella</i>	Puerto Rico and USA	March, 2013	No illnesses reported	Recall of more than 23,000 units (approximately 102,000 pounds) of chicken products that may have been contaminated	CDC 2014
Whitestone cheese	<i>L.monocytogenes</i>	Australian and New Zealand	March, 2014	No illnesses reported	Recall of Windsor Blue cheese in four?? Australian and New Zealand	MPI 2014
Crave Brothers farmstead cheeses	<i>L. monocytogenes</i>	USA	September, 2013	Six ill persons hospitalized. One death in Minnesota	Recall of Waterloo Wisconsin truffle cheese products with make dates of July 1, 2013, or earlier, due to possible contamination	CDC 2014
Sprouts	<i>E. coli</i> O104:H4	Europe and North America	May, 2011	More than 4,000 persons infected	Ban by the European Union of the importation of fenugreek seeds and various other seeds, beans, and sprouts from Egypt that were the source of the sprouts responsible for the outbreaks in Germany and France	WHO 2011
Nice & Naturals Nutritious Balance	<i>Salmonella</i>	New Zealand	December, 2014	No illnesses reported	Recall of Nice & Natural Nutritious Balance nut mix	MPI 2014
Fresh cream	<i>E. coli</i>	New Zealand	January, 2014	No illnesses reported	Recall of 8,700 bottles of fresh cream that had been distributed to retail and foodservice outlets	MPI 2014

However, in recent years, these bacteria have been linked to infections in a wide range of food products, including fresh products, processed meat products and juices. Symptoms of infection by pathogenic *E. coli* strains can lead to severe illnesses (Yoda et al. 2014) such as diarrhoea, fever or even death, especially in children and aged persons.

L. monocytogenes is another pathogenic bacterium that has caused a number of food outbreaks over the last decade. Dairy products are the main vehicles associated with foodborne illnesses with the capability to affect infants and the elderly. Unlike other bacteria, infection by this bacterium has a high fatality rate of 20–30% (Gillespie et al. 2009), and the annual estimated economic loss is \$2.6 billion in the USA (Hoffmann et al. 2012). *L. monocytogenes* has been the most infamous foodborne pathogen in Australia because of its high numbers of fatal cases and substantial economic losses of \$1.2 billion per year (Popovic et al. 2014). One of the most serious listeriosis outbreaks was reported in Europe in 2009-2010. The reported data showed a total of 26 people were infected with eight fatalities in three different regions (Schoder et al. 2014). In Australia, five outbreaks caused by *L. monocytogenes* infections between the years 2001–2010 led to 57 cases and 14 deaths (Scallan et al. 2011). In New Zealand *L. monocytogenes* was associated with one outbreak between 2011 and 2013, and has caused six reported illnesses cases (ESR 2011; ESR 2012; ESR 2013). The severity of listeriosis and the difficulty of avoiding *L. monocytogenes* in the environment have highlighted the importance of having a food safety system against *Listeria*. However, listeriosis outbreaks have recently been connected to the ability of a food to harbour viable *L. monocytogenes* through the manufacturing process (Hoelzer et al. 2012) and were, also, often associated with inappropriate storage processes.

Information about the number of outbreaks caused by each pathogenic bacterium, the number of reported illnesses and the associated food vehicles, are well-documented in many western countries, including New Zealand. This information is used to estimate the economic losses and highlight food safety issues in the FSC but is probably underestimated because many foodborne illnesses are not reported unless they are severe. The information presented later in the thesis (Chapter 4) suggests that the pathogenic bacteria associated with foodborne outbreaks are a major cause of foodborne illnesses and will have a considerable influence on future efforts to enhance food security.

2.3 Food safety and food security

Compromized food safety from infections could disrupt the supply of food at any time and create the condition of food insecurity. Food safety, therefore, implies the delivery of a product that is uncompromized in terms of microbial contamination through the FSC. A supply chain strategy emphasizes the management of all food safety issues that can arise due to improper transferring, handling and distribution of the product (Xuexin 2011; Giacometti et al. 2012). In fact, when managing food safety, it is essential to implement proactive strategies to minimise the probability of delivering an unsafe product. Ensuring this will reduce food scares and food losses. Many studies have investigated different stages in the FSC where there was a lack in the food safety strategy.

A recent study investigated the occurrence of *L. monocytogenes* in 12 meat and dairy products from small-scale direct marketers in Europe (Muhterem et al. 2015). The study categorised these food business operators into uncontaminated and contaminated sectors according to the previously available *L. monocytogenes* occurrence data for each food business. Their data showed that *L. monocytogenes* was a common coloniser of food processing environments in European food processing factories. There was also a consistent cross-contamination risk existing through FSC facilities. The results of this study revealed the effect of environmental factors causing cross-contamination during food production that can lead to significant food losses if poor hygiene practices were in place. Therefore, the influence of environmental factors on foodborne outbreaks and food security is a widely debated and investigated issue.

Foodborne illnesses associated with the consumption of specific food products, such as fresh produce, cause serious issues for public health (Liu et al. 2013; Ilic et al. 2008). According to international organisations (FAO/WHO) agro-food products represent the greatest concern in terms of microbiological hazards that influence public health (Naumova et al. 2007; Huang et al. 2003). In China, one of the rapidly developing countries, agro-food products account for more than 70% of the total food consumption (Jin et al. 2008). This has prompted the Chinese government to establish efficient food control systems to reduce foodborne illnesses and foodborne outbreaks caused by agro-food products. Many studies have investigated the difficulties and problems in the FSC which have delayed the establishment of food control systems in China (Yang et al. 2012). They revealed that a lack of agro-food legislation and food safety structures were major obstacles, and the absence of an effective food safety system can lead to an increase in the numbers of foodborne illnesses and foodborne outbreaks, which can, consequently, lead to food insecurity.

The production and consumption of foods, especially fresh produce and agro-food products, involves growing, transferring and handling food under different conditions (Fraser 2006). If food safety is compromised it can lead to food spoilage and microbial food contaminations in the FSC (McMichael et

al. 2005; Huang et al. 2003). A research report from Canada investigated the relationship between the incidence of *Salmonella*, pathogenic *E. coli* and *Campylobacter* infections, between 1992 and 2000 in two Canadian provinces using weekly reports of confirmed cases of the three pathogens (Fleury et al. 2006). The results showed that there was a strong association between the ambient temperature and the occurrence of all three enteric pathogens. Pathogenic bacteria are present in the food processing environment because of their saprophytic lifestyles (Ferreira et al. 2014). An inadequate hygiene system, poor hygiene practices and unhygienic design of equipment may cause pathogenic contamination of the food manufacturing plants (Almeida et al. 2013). This contamination can be the initial step in the transmission of pathogenic bacteria from their original source in the food plant to food processing elements (Alali et al. 2013) and, ultimately, to the consumer, where they cause foodborne illnesses and outbreaks.

Many countries have evaluated their current food control systems in order to protect consumers from chemical and microbiological hazards. (Alomirah et al. 2004; Yang et al. 2012). For example, two national studies were conducted in Kuwait and in the Sultanate of Oman on the effectiveness of their current food management systems and elements, including the food control system for food producers, implementation of food legislation, food inspection protocols and the use of accredited food testing laboratories (Alomirah et al. 2010; Al-Busaidi and Juke 2015). Both reports highlighted deficiencies in the development of standards relating to food safety and quality, and the weak inspection systems for food and food products at different stages during production and processing. Without addressing these problems, food losses and food insecurity are unavoidable. The impact of unclear information and knowledge among stockholders and food handlers about the importance of food safety control can result in an ineffective food safety system.

Uncertainty of the food service sectors in the FSC and limited knowledge of food safety strategies can negatively affect food safety control during production and handling (FAO 2009; Wu 2012). An inadequate food safety training system for food handlers contributes to an increase in microbial food contamination incidences (Chapman et al. 2010). With the recent increase in global food production, some international food manufacturers are relying on third parties to produce and export thousands of tonnes?? of food ingredients. Inadequate food safety training for these third parties that would be handling food in the early stages of food manufacturing, can lead to an increase in the numbers of foodborne outbreaks. Consequently, this will cause a significant loss of food products, damage the reputation of the international food manufacturing companies as food producers and, ultimately, influence food insecurity. Thus, information and education about food safety and quality issues for food handlers across the FSC is important and can have a significant impact on reducing food safety problems and improving food security. It is now clearly evident that a national food safety

management system is important for any country and, if compromised, can result in a significant increase in food losses in the FSC and foodborne incidents and can, ultimately, lead to food insecurity.

2.4 Improved microbial food safety in the FSC is vital to enhance food security

A food safety management system is an important element in controlling the safety and quality of foods prepared for consumption by consumers. An improvement in food safety control systems in the FSC can significantly reduce microbial contamination of foods (Manzini and Accorsi 2013). Therefore, it is necessary to understand the management of the FSC to improve microbiological food safety. Currently, food industries apply different food safety controls in their food safety management systems. However, in practice, the functioning of such systems is variable. The importance of having a well-managed operation at each step within the FSC will ensure the control and sustainability of product quality. The world is facing a challenge to reduce food losses, as a large amount of the food currently produced globally is lost. Therefore, the management of different aspects of the FSC has a vital role in improving food safety and minimizing the risk of food insecurity.

The primary materials for food manufacturing, such as milk, meat, fruits and vegetables, have been implicated as sources of infection that may cause microbial contamination, food outbreaks and economic losses (Table 2.1). Farmers are responsible for supplying the consumers and manufacturers with the raw products for use in food manufacturing and processing. Fresh produce and raw products receive special attention because they might contain pathogenic bacteria, such as *Salmonella* spp. and *E. coli* O157:H7 (Girones et al. 2010; Khan and Husain 2007; Al-Lahham et al. 2003). This has demanded the use of Good Agricultural Practices (GAP) in both crop and animal farms at the ~~pre-on~~ farm stage, in order to reduce microbial contamination risks (Lehto et al. 2011; Little and Gillespie 2008) and to decrease total food losses. Practising GAP includes all activities before, during and after production and harvest. GAP also requires product inspection reports from suppliers, and these are essential records to ensure that the products are not contaminated by pathogens or toxins. Thus, applying GAP and more hygienic procedures in the farming stage is important to ensure maximum safety of the products. However, food safety control systems are also important in other stages of the FSC to ensure the production of safe food.

An ever increasing number of food outbreaks around the world are reported each year because of cross-contamination linked to processed foods (Pointon et al. 2006; Ross et al. 2009; Olsen et al. 2005). Poor application of HACCP principles can result in microbial contamination during food processing (Sampers et al. 2010; Capps et al. 2013).

Processed and ready-to-eat meats are, potentially, a vehicle for foodborne illnesses associated with *Clostridium perfringens*, *Salmonella*, *E. coli* (EHEC) and *L. monocytogenes* in many countries, including Australia (De Valk et al. 2001; Sim et al. 2002). An increase in the incidence of foodborne outbreaks by

these bacteria during manufacturing (Pointon et al. 2006) has resulted in the identification of specific risk profiles for these bacteria in different foods to provide the industry with risk ratings for hazardous meat and meat product combinations (Sumner et al. 2005). Such development of risk management systems and the implementation of HACCP-based food safety strategies across the supply chain for different food products are essential for all countries to reduce food poisoning outbreaks and improve global food security.

Applying HACCP or a similar system of hazard control in food manufacturing businesses is important to control hazards and, thereby, improve the safety of food (Mantovanelli et al. 2001; Mortimer 2001) (Table 2.2). Nevertheless, many recent studies have suggested that a combination of two or more safety control programmes, such as ISO, GMP and/or HACCP, improves microbial food safety management markedly (Arvanitoyannis and Sakkomitrou 2012; Afoakwa et al. 2013) and, thereby, reduces food contamination. Implementing one or more of these systems during food production is, therefore, widely recommended for food manufacturing businesses to achieve more effective food safety systems and improve food security.

Table. 2.2 Most common microbial contamination issues and the possible solutions using a food safety management system

Microbial contamination issue	Frequency/impact	How to improve	References
Contamination of raw materials	<ul style="list-style-type: none"> Fresh vegetable products implicated as sources of infection Inappropriate suppliers' process, or wrong storage, may cause microorganism contamination 	<ul style="list-style-type: none"> Apply good agricultural systems and more hygienic performance in both crops and animal farms Establish effective cleaning/sanitizing programmes Request a product inspection report from the suppliers that contains a self-evaluation document to ensure the materials were not contaminated by pathogens or toxins 	(Wu et al. 2014; Gustavsson et al. 2013; Lehto et al. 2011)
Risk in food packaging	<ul style="list-style-type: none"> Air combined with packaging on FSC is one of the major potential sources pathogenic microbial contaminations 	<ul style="list-style-type: none"> Use appropriate air filters combined with production process at all times that can control high-risk microbial aerosol generation Use good hygienic practices in food processing and supply a product inspection report form to ensure the products are not contaminated by pathogens or toxins 	(Harris et al. 2014; Who 2010)
Risk in food refrigeration	<ul style="list-style-type: none"> Inappropriate refrigeration systems can cause microbial contamination that can result in a big loss of food products 	<ul style="list-style-type: none"> Refrigerate food products as that should produce a safe product by reducing the temperature of the meat and vegetables to a point where the rate of growth of spoilage microorganisms is reduced and the growth of most pathogenic microorganisms is prevented Supply a refrigeration inspection report 	(Carpentier et al. 2012; Sampers et al. 2008; James et al. 2006)
Risk in transportation and food service operations	<ul style="list-style-type: none"> Unsuitable and untimely transportation services can cause microbial contamination Product handling at the end destination and/or at wrong temperature can cause microbial contamination and food loss 	<ul style="list-style-type: none"> Employ time and temperature control in all stages of transportation Use good personal hygiene Establish effective cleaning/sanitizing programmes Supply product inspection report forms at the product destination for all products from the initial process to the ultimate end products 	(Linton and McSwane 2013; Hassouneh et al. 2012; Githaiga 2012)

Chapter 3

Microbial contamination and economic loss: Case study of a New Zealand food scare

3.1 Summary

Aim: To investigate the effect of the Fonterra milk powder contamination scare in New Zealand during August 2013 and its impact on economic loss and implications to food security.

Method: An incidence of a whey protein concentrate (WPC 80) contamination was investigated by examining the reports by Fonterra and MPI to draw a timeline and highlight each action and reaction by the affected manufacturing firms and MPI. Additionally, media and economist's reports were used to explain the actions taken by firms and countries that were affected by the WPC 80 contamination incidence. Consumer surveys were conducted in supermarkets to examine public awareness and the changes in consumer behaviour within New Zealand in response to the incident.

Results: Gaps in the food safety management system, including misidentification of the organism responsible, was the reason for the WPC 80 milk botulism scare. The contaminated product was used as micro-ingredients in a large number of consumer products. Therefore, this incident caused huge food and economic losses. Fonterra's botulism scare had a negative impact on New Zealand's exports and, hence, the economy. A consumer survey showed no change in the domestic consumption of Fonterra's products following the incident. However, this incident increased the public awareness about the importance of food safety.

Conclusion: The likely cause of the WPC 80 contamination was *C. sporogenes* causing food spoilage not *C. botulinum* as suspected earlier. The outcome data provided evidence to support the fact that the Fonterra botulism scare had a significant impact on New Zealand economy and occurrences of similar incidents could seriously jeopardise food security.

3.2 Introduction

In order to achieve food security and allow food commodities and products to flow from the areas of surplus to the areas of deficit in local, national and global markets, effective and functional food safety management practices in the manufacturing and production of foods has to be in place (Bryden 2012; Bosona and Gebresenbet 2013). Food safety systems in the FSC can have serious impacts on consumers around the world as an inadequate food safety system can cause food contamination and foodborne outbreaks and, eventually, a food insecurity problem. Bacterial pathogens are the most prevalent contaminants in food products (van Boxtael et al. 2013). These contaminants can occur at any stage in the FSC, starting from agricultural production and post-harvest processing, and through to distribution and consumption. Increases in foodborne outbreaks and food scares cause significant food and economic losses worldwide (Knowles and McEachern 2007; Ribera et al. 2012; Yang 2013). Such huge and ongoing losses are the reason why many countries, particularly industrialized nations, have established food safety guidelines and standards (Winchester et al. 2012; Nestle 2013).

Globalisation of the food trade is one of the factors thought to be responsible for the increased number of foodborne outbreaks and food scares caused by microbes (Al-Busaidi et al. 2015; Aung and Chang 2014). In countries, such as New Zealand, Australia (Lawrence and Wallington 2013) and the USA (Headey 2011), food products make a significant contribution to their annual exports. Therefore, food contamination incidents can have a severe impact on the economic performance and Gross Domestic Product (GDP) of the countries involved.

New Zealand's annual exports are NZ\$13.7 billion and one third of these exports come from dairy products alone (Statistics New Zealand, 2013). The success of this country's large scale dairy industry was built on good grass farm management systems, combined with immense research progress and expansion into the international market for up to 95% of New Zealand's milk production (Lees et al. 2015). Three New Zealand dairy companies, including Fonterra, have expanded into several overseas markets. Fonterra is the largest dairy producer in the world and controls one third of the international dairy trade; it exports its products to about 140 countries (Fonterra 2012). The reputation of Fonterra products has been built on its leading brands and high quality food. This reason alone makes any food outbreak and/or food scare in the Fonterra dairy sector have a significant impact on New Zealand's dairy exports and, as a consequence, markedly affect the country's economy. The Ministry for Primary Industries (MPI) is the food safety regulating authority in New Zealand. It is responsible for administering the Food Act 1981 and implementing food safety programmes to meet the regulatory requirements for food businesses.

A number of studies have investigated the general effects of foodborne outbreaks and food scares around the world. For example, China's melamine milk scandal and its implications for food safety regulations (Pei et al. 2011), the economic analysis of food safety compliance costs and foodborne illness outbreaks in the USA (Ribera et al. 2012), and the effect on trade of the European food safety standards in Africa (Otsuki et al. 2001). However, very few studies have been undertaken in New Zealand. It is important to study the effects of foodborne outbreaks or food scares in a country such as New Zealand as it not only has an impact locally but also internationally.

3.3 Aim and scope

This chapter investigates the possible impact of a Fonterra whey protein concentrate 80 (WPC 80) contamination in August 2013 on the domestic and international markets and the potential for economic losses to New Zealand caused by the incident. The main objectives were to:

- (a) Explain the WPC 80 contamination using a timeline to highlight the importance of an error free food safety system during food production.
- (b) Describe the impact of such a scare on the international market and New Zealand's economy and the reaction from countries importing dairy products from New Zealand.
- (c) Examine the domestic consumers' awareness about the foodborne scandal and investigate any changes in consumption of Fonterra's products.

3.4 Methods

3.4.1 Published Reports

Reports by Fonterra and MPI about the Fonterra food scare in August 2013 were used to explain the issue of WPC 80 contamination. These reports were used as the source of information to draw a timeline (Fig.3. 1) to point out each action and reaction by the food companies and MPI. Data published by economists as well as media reports from New Zealand and overseas were used to describe the reactions of the importing countries, the consequences, and the impact of this incidence on the international market and the New Zealand economy.

3.4.2 Consumer survey

Part of this research examined public awareness of the scare and to determine if there were changes in consumption of Fonterra's products when the contamination was announced and after the food was declared safe. The survey used some of Fonterra's products regardless of whether they were involved in the botulism food scare or not, and also some third party food products that had used WPC as an ingredient in their products (see Appendix 1). The survey also examined public awareness of the foodborne scandal, and if there were any changes in consumption rates of selected Fonterra products at the time the New Zealand government announced of the potential contamination and after the food product was cleared of any harmful contamination.

The survey was conducted by directly approaching general customers (110 customers) in supermarkets in the Canterbury area (Lincoln New World supermarket – Hornby Countdown) . Survey forms were also sent to staff members and postgraduate students at Lincoln University. The survey sampled different age groups (from 16 years to >60 years), both genders (males and females) and different ethnic groups (New Zealand, Australian, Chinese, etc.). The questions asked were if the customer: a) was aware of the botulism food scare; b) had purchased any of the listed products prior to the food scare and if he/she had stopped buying these products at the time of the government announcement of the outbreak; and c) had gone back to buying the same products after the New Zealand government cleared the food product as not contaminated? If so, how long after the government announcement did it take for the consumer to start purchasing these products again? The answers to the abovementioned questions were used to demonstrate the responsiveness of consumers towards a foodborne scandal; to show how effective the role of the media was in encouraging public awareness; and to get an idea of how many customers (as a percentage) were consuming Fonterra products.

3.5 Results

3.5.1 Timeline for the contamination

In May 2012, one piece of plastic contaminated one of three batches of WPC 80 in a Fonterra plant in Waikato, New Zealand. These three batches continued into the processing stage. Subsequently, a total of 38.2 metric tonnes (MT) of WPC 80 were stored until the end of 2012 but later 21.1 MT were shipped to China, Malaysia, Saudi Arabia and Vietnam, and the rest (17.1 MT) were transferred to other Fonterra locations for further processing into consumer products. Testing carried out at the Fonterra site in Darnum, Australia, in March 2013, revealed the presence of clostridial bacteria.

From 31 July 2013, AgResearch, carried out intensive sample testing over the following months and indicated the possibility of the presence of *Clostridium botulinum*. On 2 August, MPI, the regulatory authority of New Zealand, announced the potential contamination by *C. botulinum*, the organism causing botulism, in all batches of WPC 80. This was followed by a public announcement on 3 August after which an extensive recall took place (Fig 3.1). The processes of the recall were very complicated because the WPC 80 had been used by Fonterra's customers in a range of products (MPI 2014), including infant formula, growing up milk powder and sports drinks. In addition, some of the WPC 80 had been exported to other customers for further processing. However, on 28 August 2013, further tests revealed that the potential contamination was not *C. botulinum* but a non-toxic strain of clostridia, *Clostridium sporogenes*.

The report of the independent inquiry into WPC 80 for Fonterra's Board in 2013, revealed that Fonterra's WPC 80 had been used as a micro-ingredient to produce thousands of tons of products and these products did not meet the manufacturing specifications required by at least one of Fonterra's customers (Fonterra 2013). At this stage, Fonterra realised how large the problem was, MPI was notified and the product was recalled (Fig. 3.1). An accredited laboratory used overseas for *Clostridia* testing confirmed that it was not a botulinum contamination. MPI suggested that because of the absence of a sulphite-reducing clostridia (SRC) test during the manufacturing process, no indicator for the quality of the hygiene standards was obtained and bacterial contamination with *C. botulinum*, causing the production of the botulinum toxin, could have occurred (MPI 2014). The problem was that *C. sporogenes* can cause a food quality (spoilage) issue, whereas *C. botulinum* had the potential to cause a serious foodborne illness and, even, death.

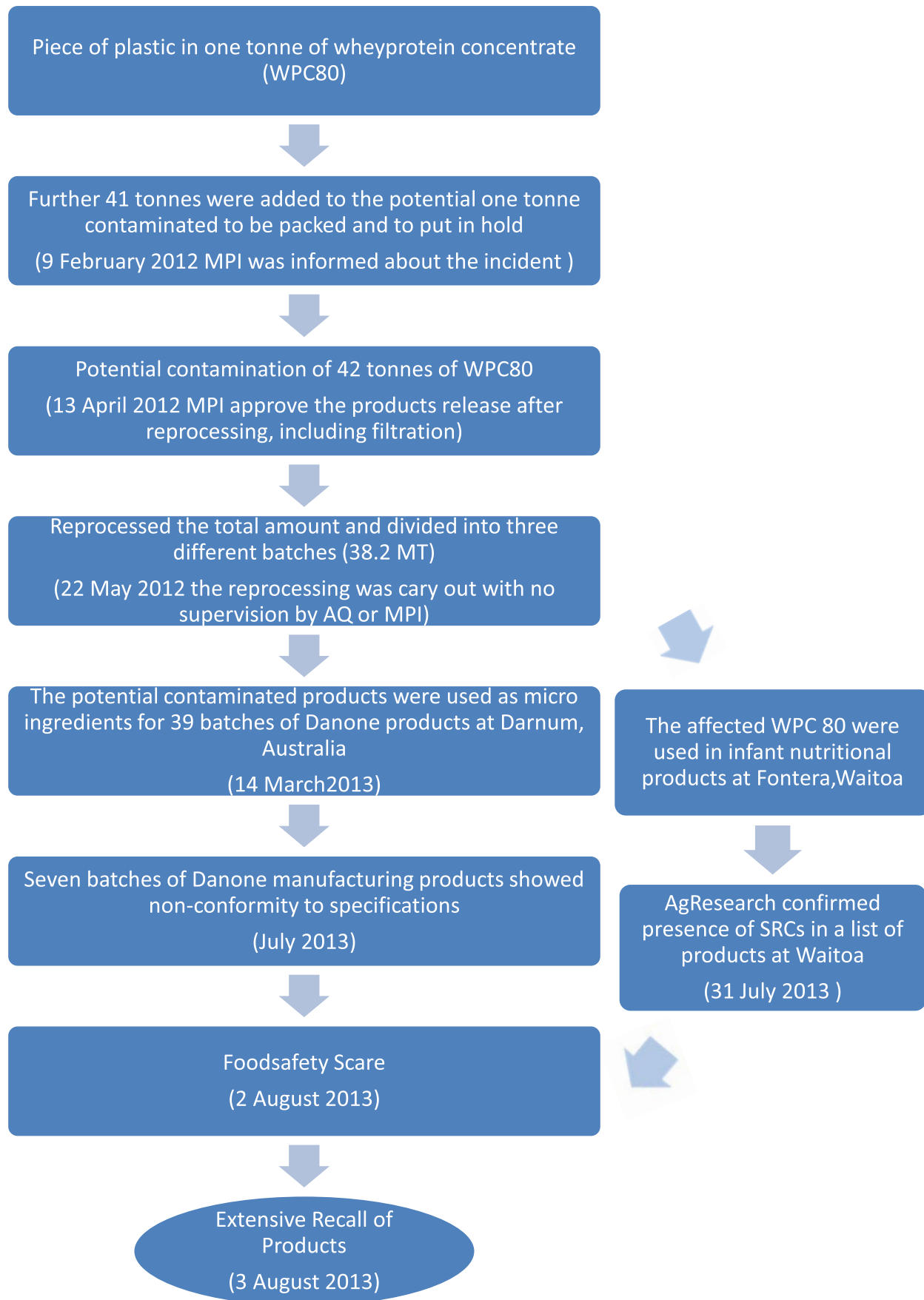


Fig. 3.1. Fonterra's food safety scare (August 2013) – timeline and background

3.5.2 Consequences and potential economic losses

On 3 August 2013, an announcement was made to the general public that 38 MT of whey protein, a key ingredient in baby milk formula had, potentially, been contaminated with a botulism-causing bacterium. Fonterra immediately instituted an extensive product recall. The recall was announced in the news media globally, including China, the largest overseas Fonterra customer. News reports estimated that the company had lost more than \$60 million in share price within hours of the MPI announcement to the public (Hussain and Dawson 2013). The company's infant formula products were recalled in eight countries, including New Zealand and China (Table 3.1). China, the second highest importing country of New Zealand's dairy products in 2012, and the largest infant formula importer (Galtry 2013), with more than 33% (\$NZ 160 million) of New Zealand's infant formula exports worldwide, banned the importation of whey protein powder and whey protein based powder products, such as casein, after the announcement of the potential contamination (Robb 2013). The temporary ban was on products containing casein and its products and did not affect the whole milk powder products, skim milk powder products or imports of infant milk formula that had already been processed in New Zealand. Chinese authorities lifted this ban for the importation of Fonterra whey powder used in the manufacture of infant formula in October 2014 (Astley 2014) but issue had already cost the New Zealand food exporters both time and money.

Media reports also showed that Russia, New Zealand's twenty-fifth largest dairy export market, with total dairy exports worth around \$105 million, in 2013, had reacted strongly. The Russian government banned the sale/importation of all Fonterra's products and its news agency advised consumers in Russia not to buy its products (Table 1). Fonterra sold \$120 million worth of products to Russia in 2012. Kazakhstan and Belarus also placed temporary bans on the importation of dairy products from New Zealand. Vietnam ordered an immediate recall and halt of the circulation of milk powder manufactured by Fonterra after the contamination scare was announced. Singapore and Malaysia also recalled some Fonterra-based dairy products as a precaution. South Korea and Saudi- Arabia required more information about the microbial testing of products using WPC80 before they accepted them (Table 3.1).

Table.3.1. Reaction by countries and companies on the announcement of Fonterra's whey protein (WPC 80) contamination

Region of action	The consequences
China	Banned the importation of whey protein powder and whey protein based powder products
Russia	Banned all of Fonterra products of whole milk powder, skim milk powder, whey protein powder and whey protein based powder
Kazakhstan and Belarus	Placed a temporary import ban on the New Zealand dairy products
Vietnam	Ordered an immediate recall on imported products from Fonterra and stopped the supply of milk powder manufactured by Fonterra in their factories
Singapore and Malaysia	Ordered an immediate recall on imported products from Fonterra
South Korea and Saudi Arabia	Ordered an immediate recall and required more levels of microbial testing on some of products
Firm of action	
Nutricia New Zealand Ltd	Recalled batches of two Karicare infant formula that it sells in New Zealand
Coca-Cola China	Quarantined a 10,560-pound shipment of whey protein, although some of the products were used in batches of Minute Maid Pulpy Milk, which Coca-Cola maintained was safe for consumption
Danone Dumex (Malaysia)	Recalled four batches of its infant formula

Customers in Australia, China, Malaysia, New Zealand, Saudi Arabia, Thailand and Vietnam were also informed of the possible contamination in their products containing WPC. Danone, one of Fonterra's customers, who received the food safety alert, is pursuing around \$270 million in compensation to cover the costs associated with the recall of infant formula products (Hussain and Dawson 2013). Williams (2013) mentioned in his report from China that a large company using Fonterra's WPC 80 as an ingredient in their infant formula brand suffered great damage to their leading infant formula brand. According to the NZ Infant Formula Exporters Association, small scale New Zealand businesses that exported infant formula products to China lost up to \$2 million in weekly sales because of the Fonterra food scare at the time of contamination announcement (Adams 2013). In China the government's temporary suspension of Fonterra products accounted for approximately three per cent of New Zealand's dairy exports to China, which were valued at \$2.6 billion in 2012. After the ban was lifted, in 2014, Fonterra stated that exports and overall trade volumes to China had improved 15 per cent in 2014 compared to 2013.

3.5.3 The consumer survey results

Consumer survey results showed that out of 130 participants, 94 had been using some of the Fonterra products but 36 were not using it at all three stages (before, during and after the whey protein scare) (Table 3.2). All participants who were using Fonterra products before the announcement of the WPC 80 potential contamination have carried on using the same products at the time of the announcement of potential contamination and after the non-contamination announcement took place. Consumer survey results showed that none of the survey participants had stopped purchasing the selected products at the time of the botulism scare. Also, the number of participants who used to purchase third party products before the potential contamination announcement was 45 (Table 3.2), and the food scare did not affect their purchasing of the affected food ingredients.

Table. 3.2. Survey of the number of participants purchasing Fonterra products regularly, occasionally or never using them

Product/s Name	Purchase regularly	Purchase occasionally	No, never
Anchor cheeses	43	60	22
Anchor Butter	62	32	28
De Winkel yoghurt	24	42	60
Country Soft spreads	33	12	73
Fresh 'n Fruity yoghurt	48	40	34
Mainland Cheese	77	28	18
Mainland Butter	56	36	32
Third party product	45		85

3.6 Discussion

In New Zealand, the food and beverage industry accounts for more than 10% of the country's GDP and the volume of this business involves approximately 2000 companies employing more than 80,000 people (Chen et al. 2015). Food products, such as milk, contribute highly to the New Zealand economy, providing about two thirds of total exports. In the year 2014, dairy product exports rose by \$4.7 billion (37 per cent), to reach \$17.2 billion. According to Statistics NZ, the increase in New Zealand exports over the last two years was largely due to an increase in dairy product exports. New Zealand's top four (ranked from highest to lowest cost) dairy products exports in 2013 were to China, USA, Japan and the Philippines (Fig .2). In 2014, New Zealand dairy products exports (ranked from highest to lowest cost) were to China, the USA, United Arab Emirates and the Philippines (Fig. 2). For New Zealand, foodborne outbreaks and food scare accidents may cause huge losses throughout many areas of the industry, such as food production, market reputation, the international food trade, and the change of consumption rates, either domestically or internationally.

The contamination occurred because of an insufficient food safety management system and a crisis management capability in Fonterra. Fonterra requested MPI for permission to reprocess /rework the product, including a filtration step, and MPI approved the release of the products after reprocessing, including the filtration step (Fonterra 2013). The rework/reprocessing instructions included the fitting of temporary flexi hoses and a 25 metre long pipe (that had not been used for two years). The rework was not audited or supervised by Assure Quality (AQ) or MPI (MPI 2014). WPC 80 products were manufactured from 100% of the reworked products (after defects corrected and inspected) so the contamination may have come from the flexi hose used during reprocessing. The MPI report also mentioned that the 100% rework was a non-standard manufacturing process and change control processes were not followed. Fortunately, the cause of the WPC 80 contamination was *C. sporogenes* causing food spoilage not *C. botulinum*, which can cause botulism, a potentially a life threatening disease. From this information, it can clearly be seen that a defect of food safety control at the stage of rework processing was the reason behind the WPC 80 contamination.

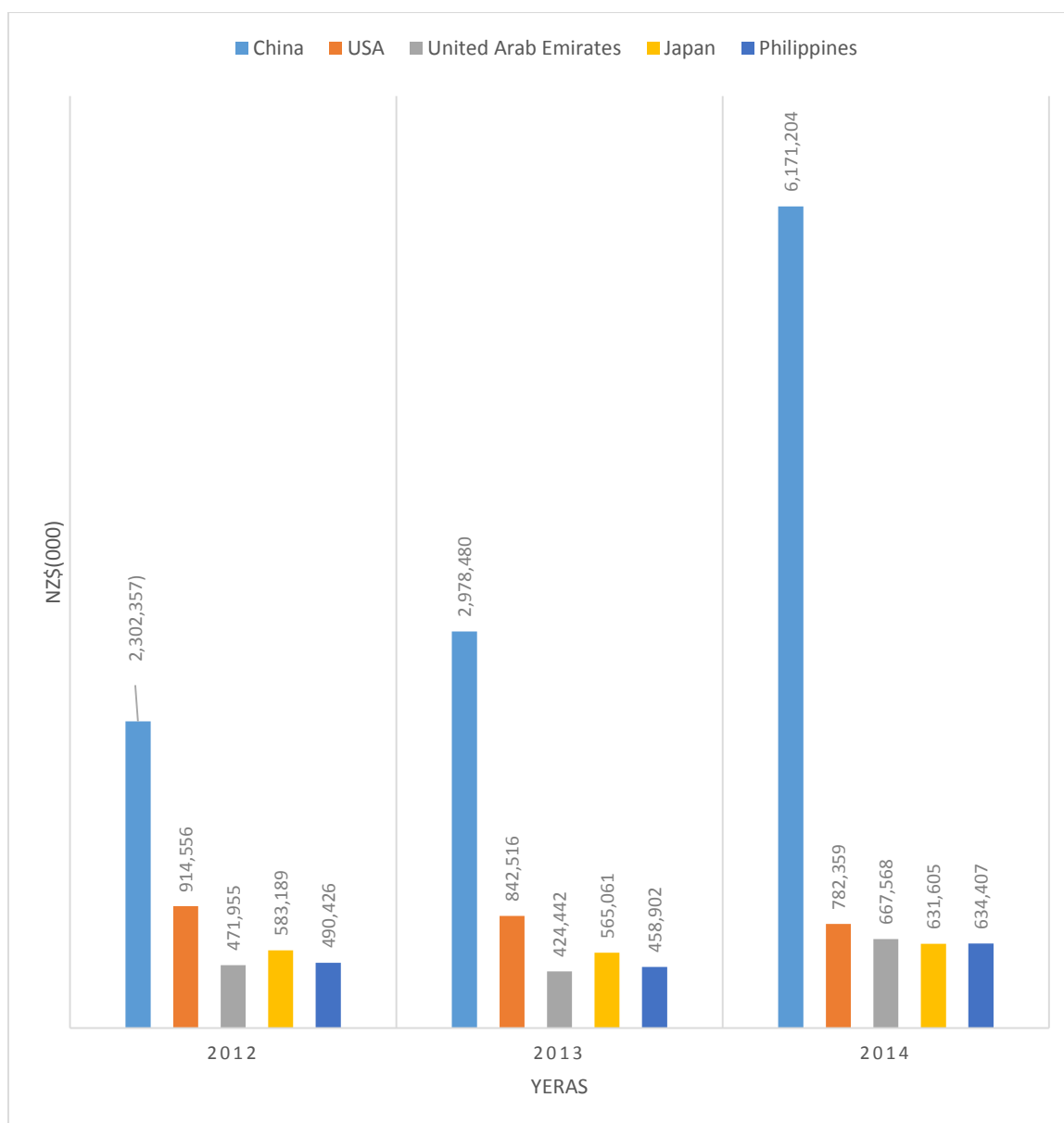


Fig. 3.2. New Zealand exports of dairy products to the top five countries per year (ranked by value) (Statistics New Zealand, 2014)

The worst case scenario was that the food was contaminated with *C. botulinum* and the most likely alternative was that the food was, instead, contaminated with the relatively benign organism, *C. sporogenes*. The use of AgResearch to undertake the identification, in the case of WPC 80, was not suitable as it was not accredited for testing *C. sporogenes* or for *C. botulinum* (MPI 2014). It is possible that the AgResearch did not follow the method correctly and, hence, release of inaccurate information about the presence of botulinum bacteria occurred.

The consumer survey results showed that most participants (73%) purchased Fonterra's products/brands while 34% purchased a third party baby food product (Karicare). Moreover, 94% of the customers were aware of the botulism food scare in August 2013, which meant that the news of the scandal spread to many in New Zealand and widespread media reports made consumers aware of the issue. There was also a rise in public awareness about the importance of food safety during this period. The survey aimed to know the effect of the scandal on the consumption rate for customers using the selected products. Customers using the selected products did not stop using them, whether at the time of the government announcement about botulism, or within/after the announcement of the non-contamination. Results showed that for customers in New Zealand, the consumption rate for the users remained at the same level before, during and after the whey protein food scare (Fig. 3.3). Customers who used the selected Fonterra products were still using the same products at the time of the government announcement about the potential contamination and the consumption rate did not change after the non-contamination announcement took place. For third party products, the results also showed that the consumption rate for the products did not change across all ethnic groups and age groups.

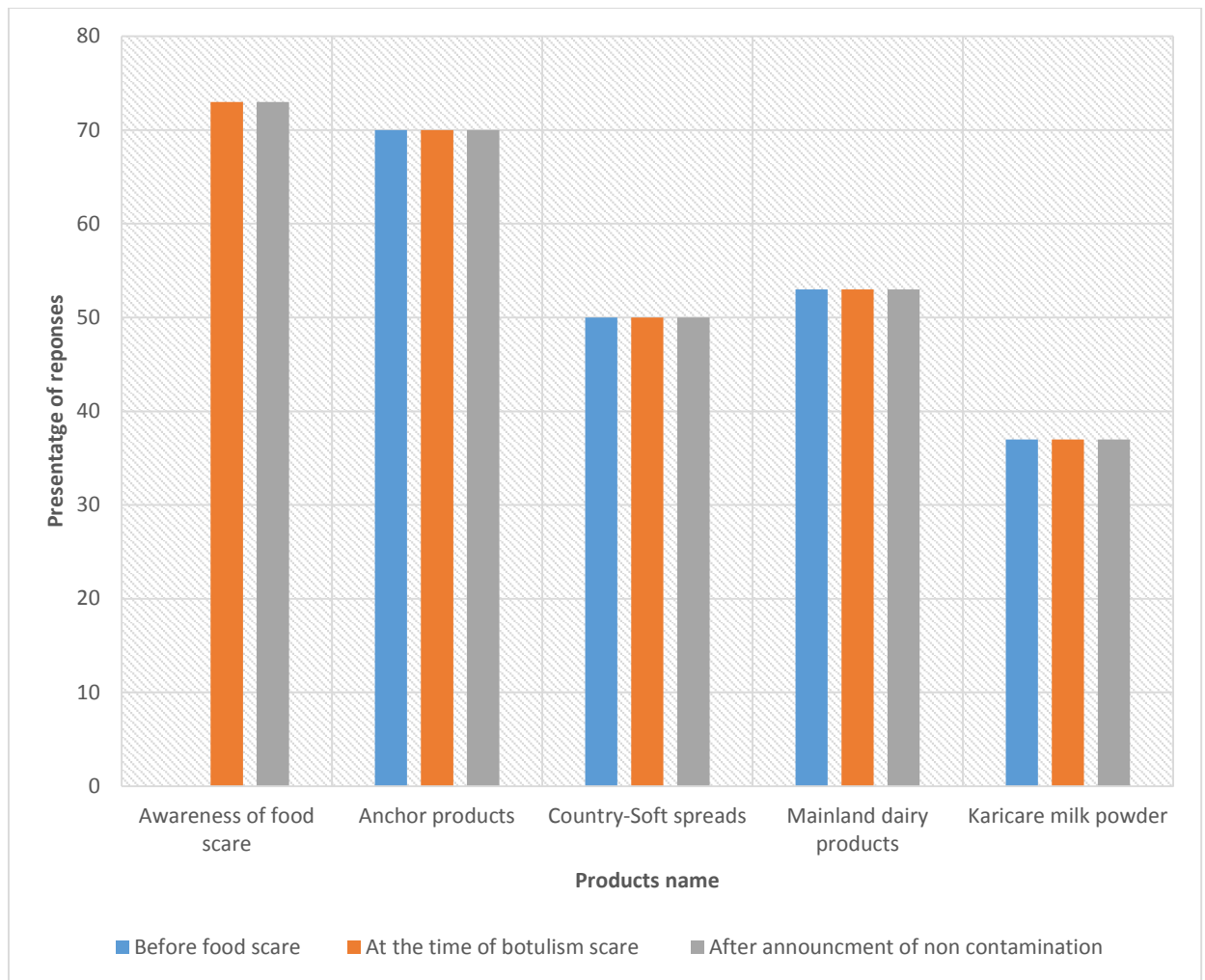


Fig .3.3. Number of customers per 100 customers who were aware about Fonterra scare and consumed Fonterra's products or third party product's at three different times

Food safety refers to foods not contaminated with unwanted elements (Pinstrup 2009). A weakness in the food safety system in a food production line can cause a significant food loss and a dramatic foodborne outbreak (Lam et al. 2013; Batz et al.). The WPC 80 food scare incident at Fonterra in 2013 has contributed to an increased public awareness of food safety and led to questions regarding the safety of New Zealand's FSC. Consequently, consumers' sensitivity towards food safety and production standards have increased. In most cases after public awareness of a food outbreak incident or food scare, the affected products could face a reduction in consumption by consumers, although after the products were permitted back on the market after controlling an outbreak, consumption levels may stay at the reduced level because of a continued potential risk from the consumers' perspective. In the case of Fonterra whey protein food scare, products that were affected had, fortunately, not been released to the domestic market when MPI banned them. However, the affected WPC 80 had been used as micro ingredients in many third party products, including infant formula milk, growing up milk, and energy drinks that had already been released into the domestic or international markets (Fonterra 2013). The results have shown that there were a wide range of consumers using Fonterra's products, as well as third party products that used WPC 80 in their ingredients. Therefore, if *Clostridium botulinum* contamination had occurred, as suspected earlier, and the affected products were released into the market, economic loss for producers, the effects on human health and the costs for medical care would have been extremely high. As a reaction to these incidents, efforts have been made to enhance food safety regulations by Fonterra and associated government groups, to improve traceability to assist with product recall, and to have better-documented decision-making processes and a more rigorous science-based risk assessment.

There are epidemiologic and methodological challenges to accurately estimating the economic burden of foodborne disease on society, either in terms of monetary costs or non-monetary units of measurement. Few studies have offered a comprehensive account of the implications of an outbreak (Lake et al. 2010, Sheerin et al. 2014, Roberts 2000, Majowicz et al. 2006). For example, Sheerin and Brunton (2014) estimated the economic costs to the community of an outbreak of campylobacteriosis resulting from contamination of a public water supply in Darfield, New Zealand. In this study, reported cases were used to identify the duration, hospital admissions and those in the paid workforce. This study reported that the dominant societal cost was lost production from time off paid work, indicating a total estimated economic cost of at least \$714,527 and it could have been even higher depending on estimates of unreported cases. In the case study reported here, neither the economic costs nor the food losses have been estimated accurately because of the limited resources and information about the Fonterra food scare in August, 2013. The potentially contaminated products were released to overseas markets but not in New Zealand. Therefore, the results of the consumer survey among the domestic customers did not reflect the potential economic loss to the domestic market. In future,

further research should be conducted to investigate the impact of such a food scare on the international food markets, especially in China because it imports many food products from New Zealand.

3.7 Conclusions

Gaps in the food safety system can lead to the production and release of contaminated and unsafe food products that can, potentially, harm consumers' health. This contributes towards food losses and also a country's economy. For an important food company such as Fonterra, a food safety scare would lead to negative economic growth and loss of business. It can also have dramatic and serious implications for New Zealand's economy. Fortunately, in the case of whey protein WPC 80 food scare, the potentially contaminated product was not released in the New Zealand market. Therefore, there was no change in consumers' behaviour towards Fonterra's products, as observed in this study. However, access to a number of foreign markets was impacted, at least in the short-term. This inevitably had downstream financial implications for those involved in the supply of dairy products associated with Fonterra. In addition, the New Zealand's reputation for high-quality, safe, dairy products internationally were affected, in addition to the confidence in New Zealand's overall food-safety regulatory scheme. It was important to have an operational food safety system, efficient traceability data to assist with product recall, and better-documented decision-making processes and a rigorous science-based risk assessment to avoid such a food scare in the future. It will not only save economic losses but also reduce food wastage, which was vital for global food security.

Chapter 4

Understanding the food security issue through food wastage and foodborne outbreak data

4.1 Summary

Aim: To collect data on the edible food waste from a number of selected households, restaurants and takeaway shops in Christchurch. These data were used to predict how much food could be wasted in Canterbury region annually and how this waste may contribute to food insecurity. Information about microbial foodborne outbreaks caused by different pathogenic bacteria in the USA, Europe and New Zealand between 2011 and 2013 were also investigated. The data were used to create a better understanding of the frequency and foods involved in different outbreaks, health risks, economic loss and to establish a relationship with food security.

Method: Food waste was measured for edible food items from 18 households, five takeaway shops and three restaurants that were randomly selected for this study. Foodborne outbreak data were collected for six foodborne diseases agents in human food from three different regions (the USA, the EU and New Zealand).

Results: Total food waste from households, restaurants and takeaway shops in Christchurch were 32.7 kg, 24 kg, and 16 kg, respectively, during a four-week period. These data were used to estimate the amount of edible food losses in Christchurch/per annum. The foodborne outbreak data included the total number of outbreaks, foodborne pathogenic bacteria involved, food vehicles associated with the outbreaks, and the number of associated foodborne illnesses for each pathogenic bacterium.

Conclusions: One third of the edible food waste produced in the Christchurch region was spoiled foods. Reducing such losses by improving food safety knowledge can be an effective step towards better food security. Also, investigating foodborne outbreaks data can improve the understanding of the relationship between pathogens causing foodborne illnesses and the associated food vehicles causing the infections.

4.2 Introduction

Food safety and food security are global issues that raise concerns about foodborne outbreaks and food losses/wastage in the FSC. The increase in foodborne outbreaks and food wastage indicate that the food safety systems in the food supply chain are not functioning efficiently. The fact that the world population is growing and is set to reach more than nine billion by 2050 requires at least a 70% increase in food production. Although most of the growth in population will occur in developing countries, developed countries can also face food insecurity (Coleman et al. 2011; Health Canada 2007). Therefore, any strategy that will help to provide extra food on consumers' tables has great value. Recently, efforts have been focused on reducing food losses (either due to wastage or microbial spoilage) through improvement in food systems. This will be one of the key strategies for enhancing the food security in the future.

Attention is given to the issue of food loss and wastage for various reasons, notably hunger and food insecurity (Beretta et al. 2013; Dogliotti et al. 2014; Liu 2014). Food loss and wastage refers to the edible food products that are produced for human consumption but not, ultimately, consumed by people. The FAO (2009) has defined food loss and waste as a decrease of food in subsequent stages of the FSC intended for human consumption. Similarly, Buzby and Hyman (2012) defined food loss as the post-harvest losses that represent the edible amounts of food available for human consumption but are not consumed, or otherwise get lost, before reaching the consumer. While food waste occurs when an edible item goes unconsumed, either before or after spoilage, as a result of human action, it is often a decision made by food businesses and/or individual consumers (Lipinski 2013). Most studies about food loss and waste have investigated losses that occur up to the retail level (Beretta et al. 2013; Oerke et al. 2012, Gunders 2012), but only a few studies have been conducted on the edible food wastage at the consumer's level (Buzby 2014; Buzby et al. 2015). Investigating edible food waste among households and food retailers is beneficial to enhance an understanding of the issues surrounding food waste. It will also offer opportunities for new approaches that may contribute to reducing waste and increasing the amount of available healthy food for humans. One of the major causes that lead to food losses and wastage is the microbial food contamination.

However, microbial contamination that can occur during food production, or after food reaches the consumer not only has an impact on increasing food losses but also can influence consumers' health and economic situation in the affected areas. The high incidence of food-related health hazards caused by microbial contamination is seen in the growing number of foodborne illnesses (Kozak et al. 2013). The increased number of foodborne illnesses affects millions of people every year and the economic cost to countries is high (Arnade and Kuchler 2013; Calvin 2014). Investigating the data of foodborne

outbreaks and having information about the associated pathogenic bacteria, number of infected people, and associated food products, will enable the food systems to cope with food safety and security challenges in the future

4.3 Aim and scope

- (a) Food Survey: This study aims to provide data on edible food waste from a number of selected households, restaurants and takeaway shops in Christchurch, New Zealand. The collected data will be used to predict how much edible food was wasted in the region at the level of households and from food retailers and its contribution to food insecurity.

The following questions items were addressed:

- What is the amount of food lost in the selected households, restaurants and takeaway shops?
 - Does the amount of food loss differ between different households and catering services, and if this is the case, why?
 - What is the relationship between food waste, food safety and food security?
- (b) Microbial foodborne outbreaks: This chapter also provides information about microbial foodborne outbreaks caused by six pathogenic bacteria in the USA, Europe and New Zealand in 2011, 2012 and 2013. These data will be used to provide a better understanding about frequency of outbreaks, the foods involved in different outbreaks, health risks and economic losses, and will contribute to establishing a relationship with food security.

4.4 Methods and approaches

In this chapter, food waste was measured only for products that were used for human consumption (waste during consumption at households and food retailers). In total, 18 households, five takeaway shops and three restaurants were randomly selected for the study. All solid and liquid foods that were discarded due to spoilage and left-overs were weighed on a daily basis during a four-week period. The study focused on both the avoidable food waste and spoiled food, which meant all waste food and raw materials that could have been consumed, except for beverages. Other bio-wastes (vegetable peelings, tea bags or bones) were not measured in the current study.

For the households, takeaway and restaurants, participants were provided guidelines on how to separate avoidable spoilage food waste from other bio-waste and how to separate left-over food that were not eaten from the waste. Small waste bags were provided to the selected household participants, while large and extra-large bags were provided to takeaway shops and restaurants. The amount of food waste was weighed and recorded. After weighing and filling in the questionnaire, participants were requested to discard the items.

Data were collected from mid-June to mid-July 2015. The selected households were chosen from the Lincoln University residential campus and from Christchurch city, both in the Canterbury region. Participating takeaway shops and restaurants were from the Selwyn district and Christchurch city in Canterbury. Information about the number of people living in each household who participated in this study, including their diet and age groups was also collected. According to Statistics New Zealand (2013), the number of households, takeaway shops and restaurants in Canterbury area were 204,840, 550 and 821, respectively. This information was used to extrapolate the findings from this limited survey to calculate the total food loss in the region.

This chapter also includes the analysis of foodborne outbreak data reported in the USA (from Centres for Disease Control and Prevention [CDC] and annual reports of foodborne disease outbreaks) in Europe (The European Food Safety Authority [EFSA] and Annual European Union summary reports on foodborne outbreaks) and in New Zealand (The Institute of Environmental Science and Research [ESR]) between 1 January 2011 and 31 of December 2013). Foodborne outbreak data were collected for six major foodborne disease agents in human foods (*Salmonella*, *Campylobacter*, *L. monocytogenes*, *E. coli*, *Clostridium*, *Staphylococcus aureus*). The data were categorised into four groups: the number of foodborne outbreaks associated with each bacterium, reported illnesses caused by the actual number of foodborne outbreaks, and the suspected food vehicle for each bacterium that caused the foodborne outbreak.

4.5 Results

4.5.1 Food waste data from the households, restaurants, and takeaway shops

Total food waste from households, restaurants, and takeaway shops during the four week survey period were calculated as 32.7, 24, and 16 kg, respectively (Table 4.1). The collected data were divided into two different groups, households group, and the pooled restaurant and takeaway shops group. Due to the limited resources (financial and timeframe) available for this study, it was not possible to include more participants. However, calculated data on food waste (Table 4.1) and the information

from Statistics New Zealand (2013) on the total number of households, restaurants, and takeaway shops in the Canterbury allowed to arrive at an estimate on the amount of food loss in the Canterbury region.

4.5.1.1 Food waste for households

Predominantly, food waste from households comprised 17.3 kg of leftovers from cooking and dining (53%) and 15.4 kg of spoiled food (47%). Spoiled foods included vegetables and fruits (17%), milk products (13%), bakery products (10 %), meat, chicken and fish (5 %), and convenience and takeaway foods (2%) (Fig. 4.1). Leftover foods included different foods prepared at home as well as convenience and takeaway foods. Foods prepared at home included porridges, sauces, casseroles, gravies and soups, while convenience and takeaway foods included ready-to-eat foods, such as hamburgers, pizza, and canned food. The estimated food waste for households in the Canterbury region was calculated and shown Table 4.2.

Table. 4.1 Food wastage from households, restaurants, and takeaway shops during a four weeks survey period

	Food waste (kg)	Average food waste per unit (kg)	Average leftover food per unit (kg)	Average spoiled food per unit (kg)
Households	32.7	1.8	0.95	0.84
Restaurants	24	8	6.1	1.86
Takeaway shops	16	3.2	0.67	1.76

Table. 4.2. Estimated food wastage (kg) for households in the Canterbury region

Type of food waste	Equation Food weight per month * 204,840 households in Canterbury region	Estimated food loss per month (kg)	Estimated food loss per annum (kg)
Leftovers and spoiled food	1.8 kg * 204,840	368,712	4,424,544
Leftover	0.95 kg * 204,840	195,417	2,345,004
Spoiled food	0.84 kg * 204,840	137,294	1,647,528

4.5.1.2 Food waste from restaurants and takeaway shops

The three restaurants surveyed produced a total of 24 kg food waste over the four-week study period (8 kg per restaurant). Leftover foods were calculated 18.48 kg (77%) while spoiled foods were calculated 5.52 kg (23%), which included fruits and vegetables at 11%, bakery products at 9%, and meat, chicken and fish at 3% (Fig. 4.2). The five takeaway shops produced 16 kg (3.2 kg per takeaway). The leftover foods weighed 3.48 kg (% needed here) and the spoiled foods, 12.62 kg (79%). The latter consisted of 50% vegetable salads, 15% fresh toppings (yoghurt, taboula, hommous) and 14% meat, chicken and fish (Fig. 4.2). The estimated total food wastage for restaurants and takeaway shops in Canterbury region are shown in Tables 4.3 and 4.4, respectively.

Table. 4.3. Estimated food wastage at restaurants in the Canterbury region

Type of food waste	Equation Food weight per month* 821 restaurants in Canterbury region	Estimated amount of food loss per month (kg)	Estimated amount of food loss per annum (kg)
Leftovers and spoiled food	8 kg * 821	6,568	78,816
Leftovers	6.2 * 821	5,090	61,080
Spoiled food	1.8 kg * 821	1,510	18,120

Table. 4.4. Estimated food wastage from takeaway shops in the Canterbury region

Type of food waste	Equation Food weight per month* 550 takeaway shops in the Canterbury region	Estimated amount of food loss per month (kg)	Estimated amount of food loss per annum (kg)
Leftovers and spoiled food	3.2 kg * 550	1,760	21,120
Leftovers	0.7 kg * 550	385	4,620
Spoiled food	2.5 kg * 550	1,375	16,500

4.5.2 Microbial foodborne outbreaks

The data on microbial foodborne outbreaks in the USA, Europe and New Zealand between 2011 and 2013 were collected and classified into four different groups to understand the relationship between foodborne outbreaks, food safety and food security. The data included the total number of outbreaks, the foodborne pathogenic bacterium involved in the outbreaks, food vehicles associated with the outbreaks, and the number of associated foodborne illnesses for each pathogenic bacterium.

4.5.1.3 Data analysis of microbial foodborne outbreaks in the USA

In 2011, among the confirmed 370 foodborne outbreaks in the USA, bacteria caused 192 (52% of outbreaks) of them. In 2012 and 2013, the number of the confirmed outbreaks caused by pathogenic bacteria increased to 208 (49% of the total food outbreaks) and 239 (54% of the total food outbreaks) (Table. 4.7), respectively.

Table. 4.5. Number of bacterial foodborne outbreaks, associated foodborne illnesses, and suspected mode of infection as reported in the USA from 2011 to 2013. (CDC 2011, CDC 2012, CDC 2013)

Pathogenic bacteria	Number of outbreaks			Number of reported illnesses			Suspected mode of infection
	2011	2012	2013	2011	2012	2013	
<i>Campylobacter</i>	23	30	20	241	434	266	unpasteurized dairy products, undercooked chicken
<i>Salmonella</i>	108	106	149	2966	3366	3553	fish, pork, minced meat, turkey products
<i>L. monocytogenes</i>	4	4	6	153	19	34	dairy products
<i>E. coli</i> (STEC)	23	29	29	237	500	409	vegetable row/raw crops
<i>Clostridium</i> spp.	2	5	12	11	19	361	fish, meat
<i>Staphylococcus aureus</i>	3	2	1	20	26	33	not detected

4.5.1.4 Analysis of microbial foodborne outbreaks in the EU

In the annual European Union summary reports (2011-2013) on foodborne outbreaks, outbreaks were categorized as having strong evidence or weak evidence. This was based on the strength of the evidence based on a detailed dataset for the reported outbreaks. In my study an analysis of only the outbreaks with strong evidence over a three year period (2011 – 2013) were reported here. The numbers of foodborne microbial outbreaks were significantly higher in the EU than in the USA. These numbers have increased gradually over the three-year period from 701 in 2011 to 763 and 839 in 2012 and 2013, respectively.

Table. 4.6. Number of foodborne pathogenic bacterial disease outbreaks, number of associated foodborne illnesses, and suspected mode of infections as reported in the EU from 2011 to 2013. (EFS 2011, EFS 2012, EFS 2013)

Pathogenic bacteria	Number of outbreaks			Number of reported illnesses			Suspected vehicle
	2011	2012	2013	2011	2012	2013	
<i>Campylobacter</i>	39	25	32	720	198	478	meat, chicken, dairy products
<i>Salmonella</i>	283	347	315	4662	5787	4371	egg and egg products, fish, mixed foods
<i>L. monocytogenes</i>	8	9	12	1476	1642	1763	dairy products, bakery products
<i>E. coli</i>	17	22	12	4275	160	282	bovine meat, raw milk, herbs and spices
<i>Clostridium</i> spp.	10	5	7	35	8	14	mixed foods, turkey meat, vegetables
<i>Staphylococcus aureus</i>	35	35	94	394	497	1304	mixed foods, cheese

4.5.1.5 Analysis of microbial foodborne disease outbreaks in New Zealand from 2011 to 2013

In New Zealand, the number of foodborne outbreaks fluctuated over the three-year study period, with 120, 110, and 122 in 2011, 2012, and 2013, respectively. The highest number of microbial foodborne outbreaks was due to *Campylobacter*. For the reported foodborne outbreaks *Campylobacter* spp. were the most commonly identified agent in poultry and dairy foodborne outbreaks whereas *Salmonella* was associated with shellfish, fish and pork foodborne outbreaks.

Table. 4. 7. Number of bacterial foodborne outbreaks, associated foodborne illnesses, and suspected mode of infection in New Zealand from 2011 to 2013. (ESR 2011, ESR 2012, ESR 2013)

Pathogenic bacteria	Number of outbreaks			Number of reported illnesses			Suspected vehicle
	2011	2012	2013	2011	2012	2013	
<i>Campylobacter</i>	11	11	16	53	51	77	chicken products, undercooked chicken, raw milk
<i>Salmonella</i>	8	11	9	42	100	45	undercooked pork, ham, minced meat, chicken
<i>L. monocytogenes</i>	0	1	0	not detected	6	not detected	not detected
<i>E.coli</i> spp.	0	3	2	not detected	63	4	not detected
<i>Clostridium</i> spp.	4	4	9	56	18	208	fish, meat
<i>Staphylococcus aureus</i>	0	1	1	0	3	2	not detected

4.6 Discussion

4.6.1 Food waste in selected households, restaurants and takeaway shops

Although households, in most cases, were responsible for almost half of the total avoidable food losses (Beretta et al. 2013), there have been only a limited number of studies conducted on food waste in households and catering shops (Silvennoinen et al. 2014; Nahman et al. 2012; Katajajuuri et al. 2014; Betz et al. 2015). A recent study by Silvennoinen et al. (2014) determined the volume of edible food waste in Finnish households. In this study, the food wastes were weighed for 380 households each time they disposed of food during a two-week period. The results were used to describe food waste over a year by comparing the purchased food amounts with avoidable food waste. The results showed that the average annual food waste was 23 kg per capita, and it was estimated that about 5% of the food was not used for human consumption and discarded as waste. The difference between the study of edible food waste in Finnish households and the present study was that fewer households were surveyed but more information comparing the quantity and percentage of leftover and spoiled foods was provided in the current study (Fig. 4.1). Cooked foods were wasted as leftovers because more food was prepared and this was the highest proportion of total food waste in the households (53%). Fruits and vegetables were the most common foods discarded because they were spoiled (17%). Milk and milk products were discarded because they were not used before the use-by date (13%). For bakery products and other convenience and takeaway foods it was because they became mouldy or undesirable due to drying out and becoming less appetising (2%).

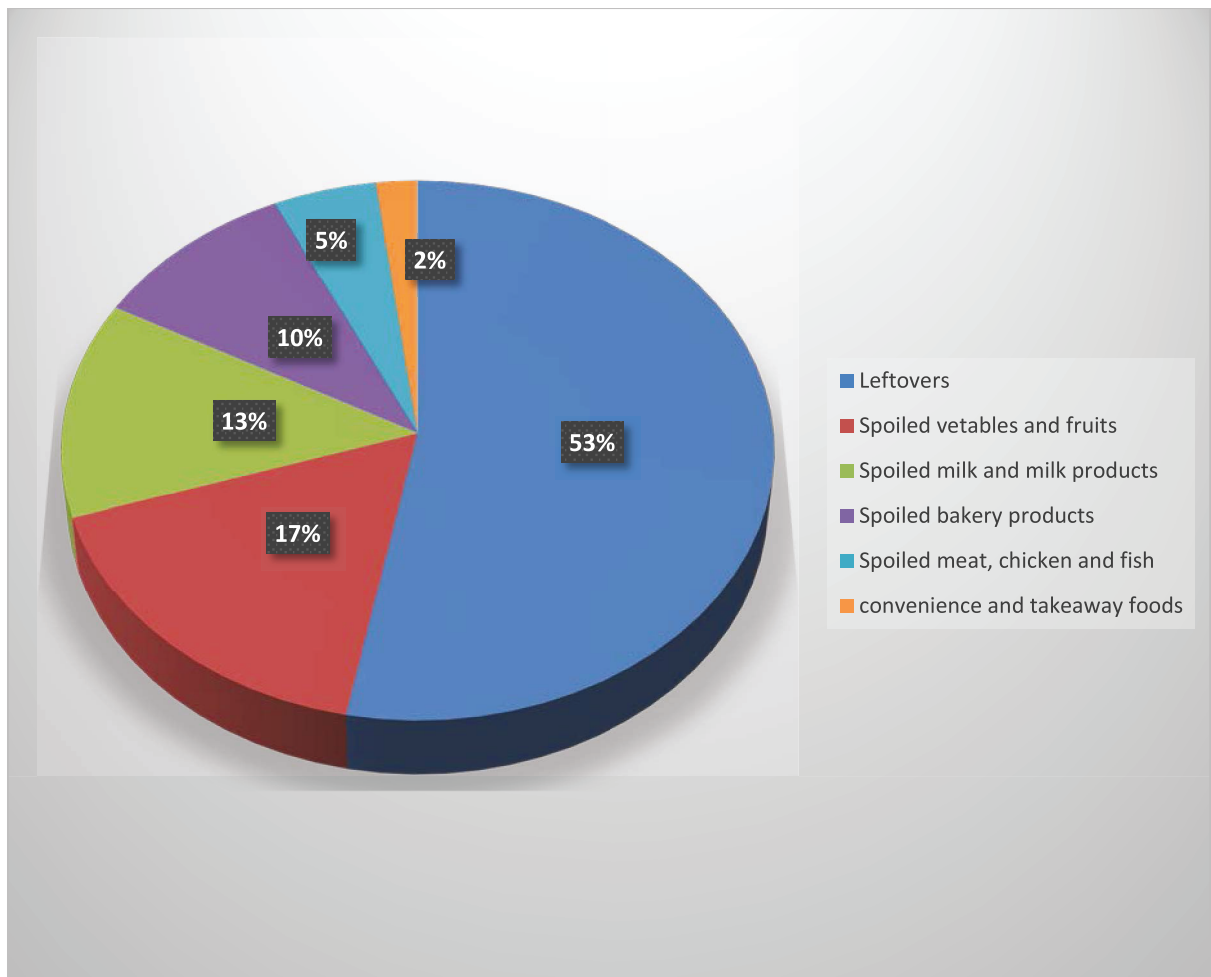


Fig. 4.1. Different types of edible food waste (expressed as % of total waste) at the selected households

In regard to food catering, a similar study by Katajajuuri et al. (2014) determined food waste from 72 participating restaurants. In this study, the foods were categorized as kitchen waste, service waste and leftovers. They also undertook a comparison between food waste at self-service restaurants and restaurants where food was prepared to order. The results showed that restaurants where food was prepared to order had more leftovers in their edible food waste. In this study, data calculated from restaurants and takeaway shops were used to compare and analyse reasons for food waste in both of the catering services (Fig. 4.2). Types and quantities of food waste varied between restaurants and takeaway shops. At restaurants, the foods disposed of were mostly leftovers or prepared in excess (77%). This meant that the amount of food waste depended more on the number of customers and the customers' behaviour. For example, most of the customers ordered more food than what they could consume. These leftovers were discarded not because the food had gone bad but as a precautionary measure to ensure consumer safety. In takeaway shops, the reasons behind food waste were mostly because the foods were spoiled (Fig. 4.2), especially vegetable salads (50%) and fresh toppings (15%). This was probably because, with takeaways, the customers were not getting served in the shop and were probably not storing this food properly during transport to their homes.

Apart from the leftovers (53%), the largest food waste items were fruits and vegetables in households, restaurants and takeaway shops, at 17%, 11%, and 50%, respectively. This was probably because they were perishable and also, in some instances, purchased in large amounts. The shelf life for the prepared vegetable salads was usually short (Rico et al. 2007) even when stored in a refrigerator. Therefore, most of the selected takeaway shops in this study were discarding their salads either at the end of the working day or the following morning, due to spoilage, drying out or changes to taste / flavour. Meat, chicken and fish products were other items that were commonly discarded as waste in households and both catering levels due to improper storage. The shelf life for most food categories was affected by the right storage conditions and temperature (Sonesson et al. 2005). Therefore, education of the public was paramount to improve the shelf life of food items.

Food loss was most prominent in restaurants and takeaway shops that served many customers, especially from unexpected fluctuations in customer numbers, cooking losses, wastage from plates and product spillages occurred (Cairns et al. 2013; Buzby et al. 2011). In the current study food loss in households occurred for a different reason, such as, product packaging issues and the number of households, which reflected on consumers' shopping behaviour. Similar results have been reported by Williams et al. (2012); Stefan et al. (2013) and Kneafsey et al. (2013). The study by Williams et al. (2012) investigated reasons behind food waste in households and noted that the type of packaging played a role in food wastage. Similarly, in this study, it was noted that the packages the consumers noted as too large (e.g. large cheese packages), or packages which were difficult to open (e.g. some yoghurt products), generated more waste as well as keeping a note of the expiry date (Fig. 4.1). A study carried

out by the Auckland Council on food waste (including bio-waste) in Auckland, New Zealand, showed a direct, positive correlation between the number of people in a household and food waste.

In the present study, the average edible food waste per household was 1.8 kg/four-weeks (Table. 4.3). This figure was extrapolated to estimate the amount of food waste generated from all Canterbury households at 4,424,544 kg per annum (1,647,528 kg spoiled food) (Table. 4.2). Also, the average food wastes from restaurant and takeaway shops were 8 kg and 3.2 kg/ four-weeks, respectively. These figures were used to estimate the total amount of edible food waste generated from Canterbury restaurants at 78,816 kg per annum (which included 18,120 kg of spoiled food) and takeaway shops at 21,120 kg per annum (which included 16,56 kg of spoiled food) (Tables 4.3 and 4.4). According to these data, over one third of the total food waste was spoiled foods and this occurred because of inefficient food storage and lack of food safety knowledge by personnel in the catering business. Thus, better knowledge about food storage may help in the use of food that would otherwise be discarded. Therefore, educational programmes designed to provide better knowledge to prevent food loss were important to reduce consumer and food service food losses.

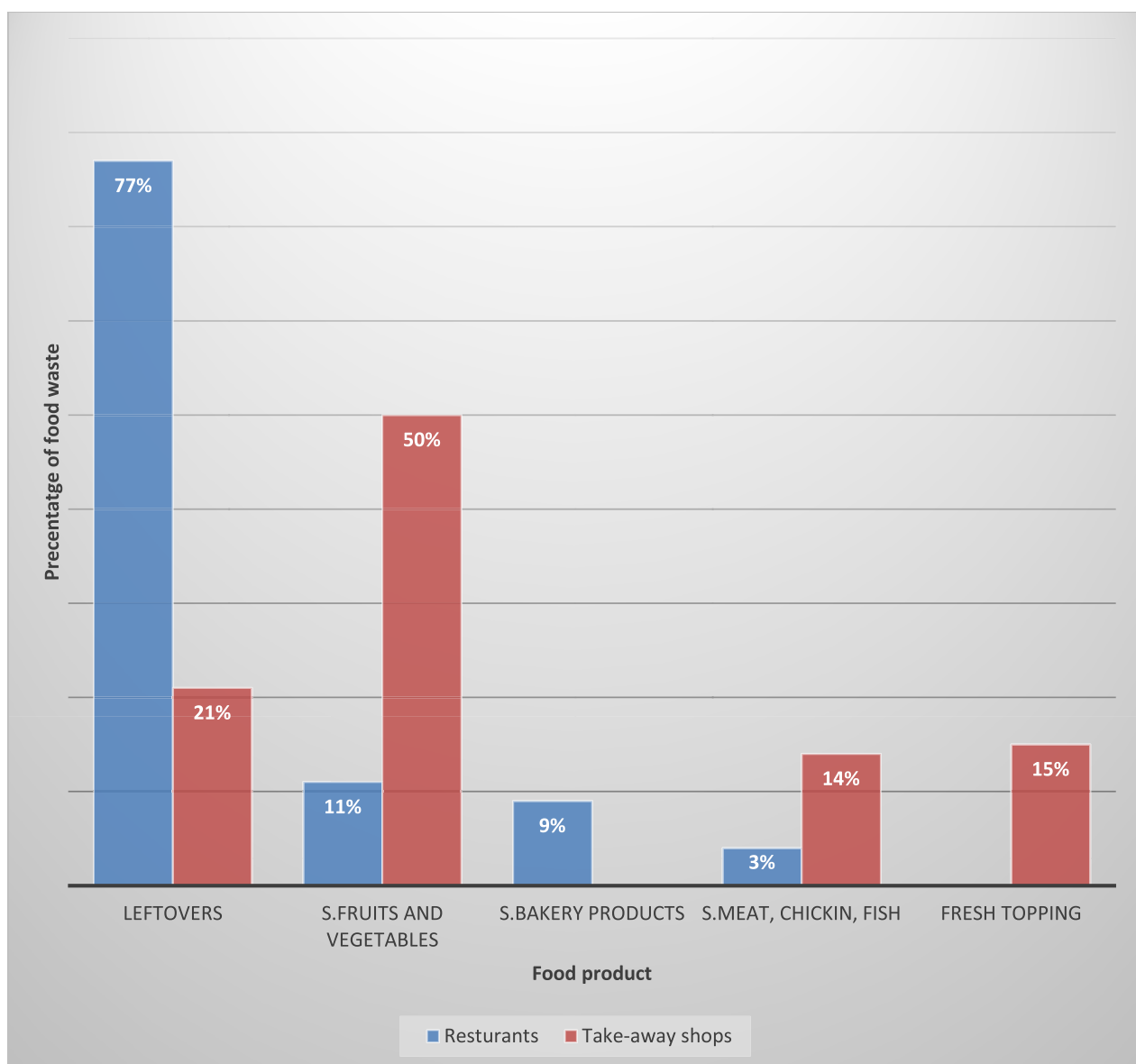


Fig. 4.2. Proportion of different kind of edible food waste at selected takeaway shops and restaurants

'S' refers to spoiled food

4.6.2 Reported microbial foodborne disease outbreaks in the USA, EU and New Zealand

Pathogenic microbes and/or other contaminants can result in food insecurity. Investigating microbial foodborne illnesses was important to categorizing the common pathogens that caused the majority of foodborne diseases around the world and cost countries huge amounts of money. Scallan et al. (2011) estimated that, in the USA each year, 31 major pathogens caused 9.4 million incidents of foodborne illnesses. The USDA Economic Research Service unit reported that the cost of five pathogenic bacteria (*Campylobacter*, *Salmonella*, *L. monocytogenes*, *E. coli* O157:H7, and non-O157:H7 STEC *E. coli*) that caused foodborne illnesses in the USA was about \$6.9 billion per annum (Hoffmann et al. 2012).

The current study investigating foodborne illnesses can be used to direct food safety policy towards lower numbers of contamination incidents; thus, improving food security. Reports from different studies published summarized foodborne outbreak data and correlated it with food safety in different ways. For example, Dewaal et al. (2006) tabulated the aetiological agents and food vehicles separately to highlight food attribution in assessing food safety hazards. The present study explored the effectiveness of foodborne outbreak data available, in international electronic reports and publications, by providing the number of food outbreaks in three countries, including New Zealand, to derive and compare these numbers with different kinds of pathogenic bacteria. The association between food categories and pathogenic bacteria was also highlighted to provide better information that can be the basis of policy discussions.

In the USA, *Salmonella* was responsible for 108, 106, 149 foodborne outbreaks and caused 2966, 3366, 3553 reported illnesses in 2011, 2012, 2013, respectively (Table 4.7). Most *Salmonella* infections were attributed to outbreaks caused by pork, turkey and chicken products. The number of outbreaks caused by *Campylobacter* has significantly declined from 30 outbreaks in 2011 to 20 outbreaks in 2013. Unpasteurized dairy products and undercooked chicken were most commonly associated with these *Campylobacter* outbreaks. *E.coli* (STEC) were involved with 23 outbreaks in 2011. This number increased to 29 outbreaks in 2013, and they were mostly associated with the raw vegetable crops food category. The most common food types causing foodborne outbreaks were fish and fish products with incidences of 30, 31, and 50 foodborne outbreaks in 2011, 2012, and 2013, respectively.

Salmonella remained the most common agent among foodborne outbreaks in the EU with 283, 347, and 315 reported outbreaks in 2011, 2012 and 2013, respectively. A significant increase in the number of outbreaks caused by *Staphylococcus* was observed from 35 in 2011 to reach 94 in 2013. This increase also resulted in a rise in reported illnesses associated with these bacteria from 394 to 1304 in 2011 and 2013, respectively. In contrast, the number of outbreaks caused by *E.coli* producing STEC and VTEC showed a reduction from 22 in 2012 to 12 in 2013. However, the highest numbers of reported deaths were recorded in 2011 with 67 fatalities, 54 were attributed to *E.coli* infections. The most common

food vehicles associated with numbers of outbreaks in the three-year study included eggs and fish products. Most of these outbreaks implicated eggs and eggs products and were caused by *Salmonella* spp, while *Campylobacter* was implicated in most dairy and chicken products as being responsible for the foodborne outbreaks. Mixed food categories were the most frequently reported food vehicle after eggs and were implicated in outbreaks caused by *Clostridium* spp., *Staphylococcus aureus* and *Salmonella* (Table.4.8).

In contrast, in New Zealand, *Campylobacter* was responsible for the highest microbial foodborne outbreaks with 11, 11, and 16 outbreaks in 2011, 2012, and 2013, respectively, compared to *Salmonella* with 8, 11, and 9 foodborne outbreaks for the same years (Table.4.3). The highest number of reported illnesses related to pathogenic bacteria were associated with *Clostridium* spp. with 208 cases in 2013, followed by *Salmonella* (100 cases), in 2012. There was only one case of foodborne outbreak caused by *L. monocytogenes* reported over the three-year period and it caused six reported illnesses. Outbreaks caused by *E. coli* (EPEC) resulted in the highest proportion of reported illnesses in 2012 with 63 cases from three outbreaks. Fish and shellfish contributed the highest number of foodborne outbreaks in 2011 and were most commonly associated with *Salmonella* infections. In 2012 and 2013, dairy products were the most frequently reported food vehicle associated with foodborne outbreaks caused by *Campylobacter* bacteria. The highest numbers of associated foodborne illnesses were linked to poultry and poultry products (Table.4.3)

By studying foodborne outbreak data, it was possible to understand the relationship between food outbreaks and food security and the resultant economic impacts (Buzby and Roberts 2009, Hoffmann and Morris 2012). The major strength in such data was that the number of foodborne illnesses associated with a particular pathogenic bacterium was based on actual observations that linked the illnesses to the type of food. However, there were methodological challenges in accurately estimating the economic losses from foodborne disease on society, especially in terms of monetary costs. Few studies have reviewed the cost estimates of foodborne illnesses (Hoffmann and Taylor 2005, Havelaar et al. 2000, Newell et al. 2010). Sheerin and Brunton (2014) estimated the economic costs to the community of an outbreak of campylobacteriosis in August 2012, resulting from contamination of a public water supply in Darfield, New Zealand as at least \$714,527, but it could have been as high as \$1.26 million if estimates of unreported cases were also taken into account. Thus, economic losses from foodborne illnesses to countries could be enormous.

4.7 Conclusions

In this study, approximately 30% of the edible food waste was due to spoiled foods. Thus, enhancing food safety knowledge among food caterers and households was an effective way to reduce food losses and, thereby, improve food security. In contrast, analysing foodborne outbreak data were a necessary and an effective step to improving understanding of the pathogen and the associated food type. The number of outbreaks attributed to the most specific food vehicle provided the best information available from the outbreak reports. The connection between pathogens causing foodborne illnesses in the population and the associated food vehicle causing the infections was the essence of food attribution. Such information would be useful for improving food safety systems for each food category.

Chapter 5

Recommendations to the Improvement of Food Security through Food Safety Management

5.1 Introduction

The projected global food demand over the next 50 years poses huge challenges for the sustainability of food production and supply. The public are much more aware of food waste now and so are concerned about hunger, the limited resources, and the environmental and economic costs associated with food loss (Wei and Yang 2012). Food losses are reported to occur throughout the world at all stages in the FSC, from primary production to food consumption (Liu et al. 2013). In developed countries most food losses are due to food wastage or from discarding it when it is still suitable for human consumption (Parfitt and Macnaughton 2010). Considerable food losses occurred during the primary production and distribution stages in both developed and developing nations. In developing and under-developed countries, most food losses were in primary production, distribution and storage, and also at the household level due to inadequate infra-structure, and the lack of a cold supply chain and refrigeration facilities.

Food safety management meant preventing biological organisms such as microorganisms, mycotoxins, parasites, toxic chemicals (e.g., pesticides) and physical hazards (e.g. foreign objects) from entering the food (Godfray et al. 2010; Yeung and Morris 2001). However, a loss of control in a food safety system at any stage of the FSC can lead to food contamination and/or a foodborne outbreak. A major foodborne outbreak could disrupt the food supply at any time and create a situation of food insecurity (Buzby and Roberts 2009). There are always potential risks from foodborne outbreaks and food losses along the FSC (Fig. 5.1). Several public and private organizations are already aware of the predicted chaotic situation in the case of an unsafe food supply. Therefore, efforts to improve food safety are part of global food security solutions (Grafton et al. 2015; Manzini and Accorsi 2013). A well-developed food safety system worked towards the delivery of food products that were free from microbial contamination and other hazards. A supply chain strategy that was based on a functional food safety system will help in minimizing food safety problems due to inappropriate transport, handling and distribution of food products (Xuexin 2011; Giacometti et al. 2012). Thus, when managing food safety, it was essential to develop proactive strategies that can help minimize the chances of the supply of hazardous food products. Undoubtedly, ensuring food safety will reduce the food losses and improve the food security.

In this context, this chapter discusses the food safety situation at different stages of the FSC and suggests practical measures that will have a major impact on improving food security.

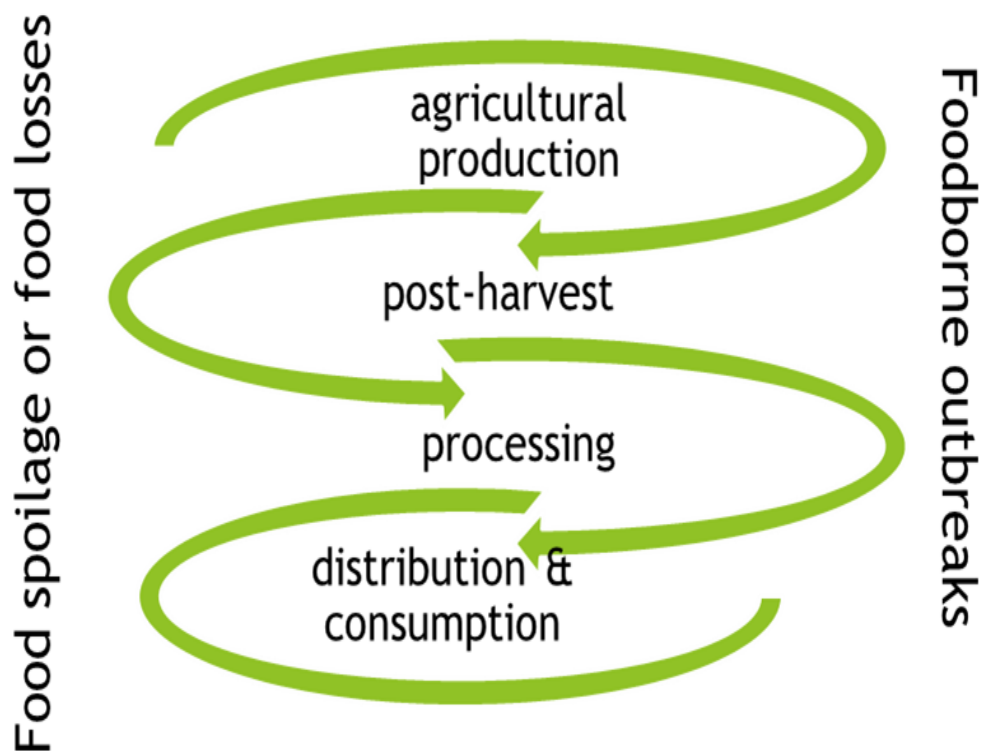


Fig. 5.1. Key stages in the food supply chain where a foodborne outbreak and/or food losses are likely to occur

5.2 Food safety management in the FSC

Worldwide, an estimated 1.3 billion tonnes of food were lost or wasted annually in its production, manufacture and distribution, and at homes (FAO 2011). The FSC was designed to deliver a quality, safe and efficiently processed food products from the farm to fork. Therefore, each operation within a stage in the FSC should aim to decrease the risk of unsafe food supplies to the consumer. Examples of food safety issues in the major stages of the FSC are presented in Table 5.1.

5.2.1 Primary production (farming)

Practically every step in the FSC can have a dramatic impact on the safety of foods. In the case of agricultural production, a range of factors can lead to fresh produce being unsafe. For example, the type of irrigation used, the source of water, the application of pesticides, as well as the farm workers' personal hygiene. Several measures can be taken to improve the quality and safety of the final product at the primary production level. Adapting Good Agricultural Practices (GAP) throughout all operations within primary production was a key to minimizing contamination and reducing food losses.

Many studies have demonstrated significant improvements in delivering more safe food when applying GAP at crop and animal farms (Trienekens and Zuurbier 2008; Calvin 2007). Irrigation and rain water have received much attention at the primary production level as they can be a source of contamination. Use of waste and recycled water that has a high probability of containing microbial pathogens, such as *Salmonella* or *E. coli* spp., could contaminate produce with these organisms (Du Plessis and Korsten 2015). Field trials have suggested that irrigating crops with raw wastewater can contaminate the produce (Hanjra et al. 2012). In contrast, the crops irrigated with treated wastewater and fresh water would be safer from contamination (Mizyed 2013). Thus, there was a demand for more research on the treatment of wastewater for growing crops in countries where fresh water was in short supply.

Table 5.1. Key food safety issues in the major stages of food supply chain that can cause food losses

Stage	Food safety issues
Primary production (farming)	<ul style="list-style-type: none"> • Contamination of irrigation water • Environmental contamination of the organic crops (heavy metals, and aromatic hydrocarbons)
Post-harvest	<ul style="list-style-type: none"> • Exposure to the surrounding environment • Inadequate storage practices
Food Processing	<ul style="list-style-type: none"> • Poor sanitation of food contact surfaces and equipment lead to growth of biofilms in food processing environment • Loss of control on food safety system during processing
Restaurants and takeaway shops	<ul style="list-style-type: none"> • Wide range of food products lead to more spoilage of foods • Products reach their expiry date before sale • Lack of food safety knowledge among food retailers
Consumption	<ul style="list-style-type: none"> • Consumers' understanding about the importance of food loss and how much food they actually waste • Too much food left over • Inadequate storage practices

Application of GAP principles on farm workers' personal hygiene can also have a significant impact on reducing the chances of transmitting pathogenic bacteria to the produce being harvested. Most foodborne diseases are transferred from humans (Crim et al. 2014) and many outbreaks have been associated with farm workers' hygiene (Monaghan et al. 2012). Farm workers may come from diverse cultural backgrounds and personal hygiene levels may vary between them. These can have a significant influence on the microbial safety of the produce they handle. For this reason, it was important to bring agricultural workers within the scope of GAP. Provision of adequate sanitary facilities and training about the importance of correct personal hygiene would reduce the probability of cross contamination and decrease the risk of food losses (Soon and Baines 2012).

5.2.1 Post-harvesting and food processing

Food products such as animal products, and some fruits and vegetables, were perishable and easy to contaminate through the environment. Many reports have suggested that disinfectant treatment of fruits and vegetables can reduce the risk of microbial contamination and reduce the possibility of cross-contamination of food (Vardar and Karabulut 2012; Møretrø et al. 2012). A range of different disinfectants and sanitizing methods were available depending on the commodity type they would be used on. For example, hydrogen peroxide, sodium hypochlorite, citric acid, ethanol and chlorine dioxide have been applied by fogging. However, those solutions may leave chemical residues on food and that can generate a health risk. Some treatments can reduce the microbial load only by about 2 log CFU/g on fresh fruits and vegetables but they were still used as sanitizing agents (López-Fernández and Simal-Gándara 2013). Therefore, studies of different disinfectant technologies, which can reduce pathogenic bacteria by at least 3 log CFU/g on fresh produce while maintaining product safety, are essential.

Food processing, particularly at the manufacturing stage, may involve human contact that can create food safety issues and lead to microbial contamination (Lynch et al. 2003). Implementation of hygiene and food safety systems, such as GMP and/or HACCP, which worked towards reducing the risk of microbial contamination during manufacturing, was recommended. The application of such systems was useful to eliminate the factors that contributed to food safety risks and pathogenic bacterial contamination. A study by Mantovanelli et al. (2001) examined the effectiveness of the HACCP system in different food industries in Italy and reported that applying HACCP had an important role in terms of controlling manufacturing hazards and can make a significant improvement to the safety of food. Nevertheless, many studies suggested that a combination of two safety control programmes such as GMP and/or HACCP would better support microbial food safety management (Arvanitoyannis and

Sakkomitrou 2012; Afoakwa et al. 2013). The implementation of these safety control applications will impact on reducing the numbers of food disease outbreaks and improve global food security.

In contrast, although using machinery during food manufacturing requires less hand work than with machinery, food products still require different processes that can affect their bacteriological safety. These processing steps could involve poor storage or refrigeration facilities (Fox and Fanning 2015; Kader 2004). These have the potential to contaminate the product with pathogenic bacteria and result in food losses. Food products, such as meat, chicken, and fruits and vegetables, could be contaminated and have high microbial loads due to hot climates. Published data have highlighted the important role of good cooling and refrigeration systems in reducing the microbial load in foods. Refrigeration of food products was carried out to reduce the temperature of food products to a point where the rate of growth of microorganisms was reduced (Kalinowski et al. 2003). The fluctuation of temperature throughout cold storage of some of foods, such as meat or chicken products, can lead to microbial growth. Therefore, ensuring the implementation of GMP and an effective food safety system would result in fewer incidences of microbial food contamination during processing.

5.2.2 Restaurants, takeaway shops and households

Food and drink wastage generated by the catering industry and households, made up a significant portion of the total food waste around the world. Limited numbers of studies have been carried out on food losses and the management of food safety at the catering and household levels. Kantor et al. (1997) found losses of up to 26% of the edible food in the food service sector and households in the USA, while Engstrom and Carlsson-Kanyama (2004) showed total losses of about 20% among Swedish food services and households. In the UK, an estimate showed that 5.3 million tonnes of food waste annually was avoidable. The above facts provided useful insights and potential opportunities to improve food security by reducing the food waste at both the food trade and household levels.

The enormous quantities of food brands on shelf displays and in a wide range in trade stores (retailers-food catering) can lead to food waste as a wide range of products reach their expiry date before being sold. Although certainly beneficial for sales statistics, continually replenishing supplies meant that food products close to expiry were often ignored by consumers. It was particularly difficult for small retail stores to manage to sell all items before the expiry dates. Activities to create awareness and enable food retailers' to their change behaviour could play an important role in reducing food waste. For example, extensive media coverage of food waste at the food trade level, highlighting the scale of the issue and providing general tips and advice, may have a significant impact in reducing food waste.

Consumer attitudes led to high food waste in developed countries. Possibly one of the most essential reasons for food waste at the consumption level in industrialized countries was that people simply can

afford to waste food. Improving consumers' understanding about the importance of food loss and raising their awareness about how much food they actually waste would play an important role in changing their behaviour towards food waste. Quested and Swannell (2011) suggested that in addition to encouraging a behavioural change at the household level, working through partners to make technical changes to the retail environment could also have a significant impact. Changes to packaging, labelling and merchandising can reinforce and complement the need for behavioural changes. A technical strategy aimed to help consumers to buy the right amount by offering the right pack sizes and using promotional mechanisms, including price reductions, will reduce the risk of food being wasted

5.3 Recommendations to improve food safety in the FSC

A good understanding of the food safety issues in the FSC was vital to developing recommendations to improve food safety. On the basis of the information and discussion presented in the previous Section (5.2), the following recommendations can be made towards a safe food supply to the consumer:

5.3.1 Primary production

1. Irrigate using a clean water source that does not contain pathogenic-bacteria
2. Promote farm workers to adhere to GAP
3. Develop effective food safety training materials

5.3.2 Post-harvest and distribution

1. Use disinfectants to reduce microbial load on fruits and vegetables
2. Have good transportation and storage facilities

5.3.3 Food processing

1. Implement hygiene and food safety systems and HACCP and/or GMP
2. Have mechanical and manual cleaning, chemical cleaning and sanitation of all processing equipment

5.3.4 Food catering and supply

1. Initiate activities to create awareness about the importance of food safety and change food retailers' behaviour to adhere to food safety measures??

2. Provide extensive media coverage of food waste in the food trade and provide general tips and advice to avoid such waste.
3. Use good storage facilities and apply food safety principles at all stages.

5.3.5 Food consumption

1. Improve consumers' understanding about the importance of food loss and raising awareness about how much food they actually waste
2. Change marketing strategies to help consumers to buy the right amount by offering the different pack sizes and using promotional mechanisms such as price reductions to reduce the risk of food being wasted.

Finally, any opportunity that can reduce food wastage, wherever it arose, was likely to remain a key focus in the future as reflected in several food security strategies.

5.4 Conclusions

A more efficient food safety system at all stages of the FSC was an effective way to reduce the amount of food lost or waste. Food safety applications may vary in the different stages of the FSC. These variations were dependent on the different factors involved in each step of food production. At the primary production level, applying GMP for better hygiene in all farm work activities will reduce food losses. At the food processing and manufacturing level, an effective food safety system, such as HACCP, can play a vital role in preventing cross-contamination and, thereby, reducing food losses. At food catering and consumption levels, media can play a vital role in raising awareness about the importance of food waste and to encourage consumers for better food utilization, which, in turn, will reduce food loss.

Chapter 6

Concluding Remarks

6.1 General Introduction

The threat of food insecurity was real and many approaches have been suggested to tackle this challenge. One third of total food produced globally never made it to consumers' tables due to several factors, including microbial contamination. Understanding food safety issues and identifying factors that contributed to food spoilage, foodborne illnesses, food outbreaks and food losses would be immensely beneficial to improving food safety systems at every stage of the FSC. A wide variety of pathogens (*e.g.*, *Salmonella*, pathogenic *E. coli*, *L. monocytogenes*, *Campylobacter*) were associated not only with foodborne illnesses and outbreaks but also with food and economic losses. Reducing microbial contamination or food safety problems could significantly improve food supply. Efficient food control and effective food quality and safety management tools (*e.g.*, GAP, HACCP, ISO and GMP) could be helpful in controlling microbial contamination. Hence, improved microbial food safety practices would definitely bring additional food to the fork.

6.2 Key findings and observations

Objective 1: Understanding the relationship between microbial contamination and economic loss and food security using a case study (Chapter 3).

Fonterra is the largest dairy producer in the world. It controlled about one third of the international dairy trade and exported its products to more than 135 countries and, therefore, the reputation of Fonterra products played an important role in the New Zealand dairy sector. It was reported in Chapter 3 that a food scare can have a significant impact on New Zealand's dairy exports, as highlighted in Table 3.1. Nevertheless, it has been found that the economic loss to the Fonterra company also had an influence on other manufacturing companies that were using Fonterra product as micro-ingredients in their products. These findings have given an estimate about the quantity of potential food losses that could occur if such a scare involved an actual contamination issue.

The consumer survey results showed that the Fonterra food scare incident in 2013 contributed to an increase in public awareness of food safety and increased consumers' sensitivity towards food safety and production standards. The potential contaminated products were not released in the domestic market, hence, the consumer survey showed no change in consumers' purchasing attitudes towards Fonterra products in New Zealand (Fig 3.3).

Objective 2: Using available information on foodborne outbreaks to explain the impact on foodborne illnesses (Chapter 4).

Information presented in Chapter 4 showed the negative effect of foodborne outbreaks on the community. Foodborne outbreaks and illness data from USA, Europe and New Zealand, between 2011 and 2013, showed that food safety issues existed everywhere and were continuously affecting the supply of food products. Data collected and analysed in this study provided useful information on the extent and frequency of microbial contamination of food products, with specific reference to pathogens and food vehicles. This information was a key to designing future food safety strategies to reduce microbial contamination and enhancing food security.

Objective 3: Generating new information on food losses due to wastage or microbial contamination in the Canterbury region (Chapter 4).

The study on edible food wastage in selected food catering outlets and households in the Canterbury region provided information that, in turn, could help in the development of new guidelines and practices for food retailers and consumers to decrease food losses. This study provided estimates of the amount of edible food wastage, which could amount to MT per year each for restaurants, takeaway shops and households in Canterbury. These numbers can be used to highlight the magnitude of the edible food wastage problem and provide ways to use the information for food security policy development efforts in the future.

Objective 4: Recommendation to improve food security through a better understanding of food safety issues in the FSC (Chapter 5).

It was shown in Chapter 5 that a lack of awareness of food safety problems and the implementation of effective control measures to reduce contamination throughout the entire FSC posed a great risk to food security. Key recommendations included designing and effectively implementing the GMPs and HACCP throughout the entire FSC, but, in particular, in the primary production and the distribution sectors.

6.3 Final Remarks

The objective of food supply chain design should be to deliver good quality and safe food products to the consumers' tables. Therefore, operations that were involved throughout the food supply should have effective food safety systems in place to minimize contamination, reduce food losses and, hence, improve food security. Each stage within the FSC could introduce different hazards to food products that could contaminate and result in a food scare with huge food losses. Such events could negatively influence the food security situation. Therefore, different food safety measures should be applied at

the different stages of the FSC. Introduction of appropriate food safety rules and regulations required accurate data and information about the reasons and/or causes of food contamination, and the associated pathogenic bacteria and food vehicles involved. The current study and similar research on a larger scale are valuable sources of data and key information that are required to significantly improve food safety and security. Thus, any effort and strategy that can decrease the number of food outbreaks would make more food available for the ever increasing human population.

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Appendices

Appendix 1: General consumer survey for the Fonterra botulism scare in 2013

Lincoln University
Department of Wine, Food and Molecular Biosciences

Master Research Student survey
Mohamed El Khishin

General consumer survey

1- Have you heard/know about Fonterra food scare (botulism) in August 2013?
Yes/No

2- Do you buy/purchase any of the following dairy products?

Product/s Name	Yes often/ regularly	Yes sometimes/ occasionally	No, never
Anchor cheeses			
Anchor Butter			
De Winkel yoghurt			
Country Soft spreads			
Fresh 'n Fruity yoghurt			
Mainland Cheese			
Mainland Butter			

3- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
Yes/No

4- Do you buy/purchase any infant formula products (Kari care and/or Kari care Gold)?
Yes/No

5- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
Yes/No

6- Do you buy/purchase Energy drinks?
Yes/No

7- Have you stopped using Energy drinks at the time of government announcement of the outbreak (botulism)?
Yes/No

Please forward it to:
Mohamed.ElKhishin@lincolnuni.ac.nz

8- Did you go back to buy any of the bellow products after the government announcement of non-contamination?

Product/s Name	Yes	how many weeks after the government announcement of non-contamination	No, never
Anchor cheeses			
Anchor Butter			
De Winkel yoghurt			
Country Soft spreads			
Fresh 'n Fruity yoghurt			
Mainland Cheese			
Mainland Butter			
infant formula Kari care and/or Kari care Gold			
Energy drinks			

9- To which Age group and gender you belong to:

- ☐ Male
☐ Female

16-25	
26-35	
36-45	
46-60	
>60	

10- To which racial or ethnic group(s) do you most identify yourself?

- ☐ New Zealand
☐ Australia
☐ China
☐ Other.....

11- Your social status:

<input type="checkbox"/> Single <input type="checkbox"/> Married <input type="checkbox"/> Married and kids <input type="checkbox"/> Other.....	<input type="checkbox"/> Student <input type="checkbox"/> Employed <input type="checkbox"/> Business/Self-employed <input type="checkbox"/> Other.....
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Thank you for your time and help.

Please forward it to:
Mohamed.ElKhishin@lincolnuni.ac.nz

Appendix 2: Sample of general consumer survey used for approaching general customers in supermarkets

Lincoln University
Department of Wine, Food and Molecular Biosciences

Master Research Student survey
Mohamed El Khishin

General consumer survey

1- Have you heard/know about Fonterra food scare (botulism) in August 2013?
☒ Yes/☐ No

2- Do you buy/purchase any of the following dairy products?

Product/s Name	Yes often/ regularly	Yes sometimes/ occasionally	No, never
Anchor cheeses		<input checked="" type="checkbox"/>	
Anchor Butter		<input checked="" type="checkbox"/>	
De Winkel yoghurt			<input checked="" type="checkbox"/>
Country Soft spreads			<input checked="" type="checkbox"/>
Fresh 'n Fruity yoghurt	<input checked="" type="checkbox"/>		
Mainland Cheese		<input checked="" type="checkbox"/>	
Mainland Butter		<input checked="" type="checkbox"/>	

3- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
☒ Yes/☐ No

4- Do you buy/purchase any infant formula products (Kari care and/or Kari care Gold)?
☒ Yes/☐ No

5- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
☒ Yes/☐ No

6- Do you buy/purchase Energy drinks?
☒ Yes/☐ No

7- Have you stopped using Energy drinks at the time of government announcement of the outbreak (botulism)?
☒ Yes/☐ No

Please forward it to:
Mohamed.ElKhishin@lincolnuni.ac.nz

Appendix 3: Sample of general consumer survey used for approaching general customers in supermarkets

Lincoln University
Department of Wine, Food and Molecular Biosciences

Master Research Student survey
Mohamed El Khishin

General consumer survey

1- Have you heard/know about Fonterra food scare (botulism) in August 2013?
Yes/No ☒ Yes ☐ No

2- Do you buy/purchase any of the following dairy products?

Product/s Name	Yes often/regularly	Yes sometimes/occasionally	No, never
Anchor cheeses		<input checked="" type="checkbox"/>	
Anchor Butter		<input checked="" type="checkbox"/>	
De Winkler yoghurt			<input checked="" type="checkbox"/>
Country Soft spreads			<input checked="" type="checkbox"/>
Fresh 'n Fruity yoghurt	<input checked="" type="checkbox"/>		
Mainland Cheese		<input checked="" type="checkbox"/>	
Mainland Butter		<input checked="" type="checkbox"/>	

3- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
Yes/No ☒ Yes ☐ No

4- Do you buy/purchase any infant formula products (Kari care and/or Kari care Gold)?
Yes/No ☒ Yes ☐ No

5- Have you stopped using any of the above products at the time of government announcement of the outbreak (botulism)?
Yes/No ☒ Yes ☐ No

6- Do you buy/purchase Energy drinks?
Yes/No ☒ Yes ☐ No

7- Have you stopped using Energy drinks at the time of government announcement of the outbreak (botulism)?
Yes/No ☒ Yes ☐ No

✓

Appendix 4: Samples of spoiled food obtained from household participants



Appendix 5: Sample of passed expiry date food obtained from household participants



Appendix 6: Sample of leftover food from restaurants



Appendix 7: Samples of spoiled foods (eggplant) from restaurants



Appendix 8: Samples of leftover foods from a takeaway shop



Appendix 9: Number of households, takeaway shops and restaurants in Canterbury region in 2013

	Number	Source
Households	204,840	Statistics New Zealand, 2013
Restaurants	821	Statistics New Zealand, 2013
Takeaway shops	550	Statistics New Zealand, 2013

Appendix 10: Sources of food outbreaks data and information in this study

Country	Source of data
The USA	<ul style="list-style-type: none">• Centres for Disease Control and Prevention (CDC)• Annual reports of foodborne disease outbreaks
Europe	<ul style="list-style-type: none">• European Food Safety Authority (EFSA)• Annual European Union summary reports on foodborne outbreaks
New Zealand	<ul style="list-style-type: none">• Institute of Environmental Science and Research (ESR)

Microbial contamination and economic loss: A case study of botulism food scare in New Zealand

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Introduction

In New Zealand, food and beverages sector accounts for more than 10% of the GDP and 2000 food firms employ more than 80,000 people. The increase of New Zealand food exports in the last three years was due to the increase of dairy products exports. This study investigates the possible impact of a food scare in New Zealand in August 2013 on domestic and international markets, and the economic loss to the industry.

Timeline of Fonterra food scare in August 2013 (botulism)

Reports published by Fonterra and MPI have been used to illustrate the problem of WPC 80 (Figure 1).

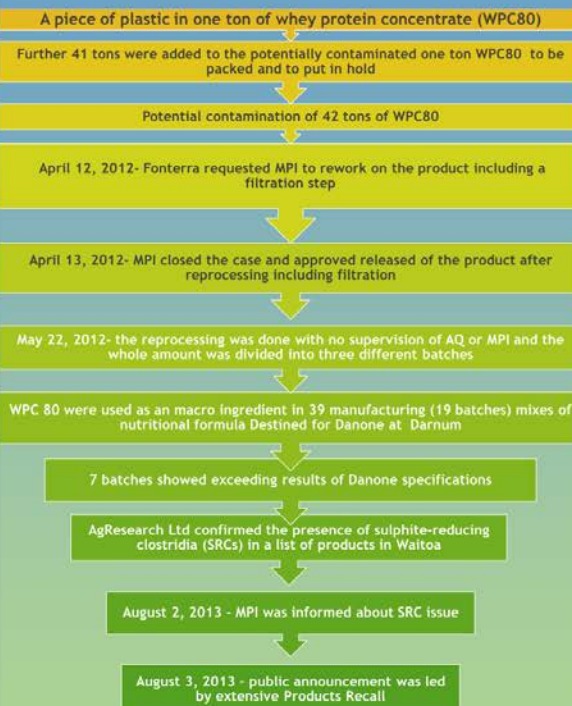


Figure 1. Timeline of Fonterra food scare (botulism) steps based on MPI report on 2014

Conclusion

Botulism food scare affected products were recalled in eight countries including New Zealand and China. This incident has contributed to increase public awareness of food safety and led to questions regarding the relationship between foodborne scare and the economic loss.

- References:-
- 1- MPI 2014. Report of pack 3b-submission part a wpc proactive. Available online: <http://food.govt.nz>
 - 2- Fonterra 2013. Report of WPC80 Independent Inquiry for Fonterra Board. Available online: <http://wpc80-inde-report.fonterra.co.nz>
 - 3- Statistics New Zealand 2014. Global New Zealand-International trade, investment, and travel profile: Year ended June 2014

Potential economic loss

Economic estimates showed that the company lost more than \$60 million within hours of public announcement (Table 1).

Table 1. React Control from countries and firms involved in Fonterra WPC80 contamination scandal.

Countries	The consequences after contamination announcement
China	Banned the importation of whey protein powder and whey protein based powder products
Russia	Banned all of Fonterra's products of whole milk powder, skim milk powder, whey protein powder and whey protein based powder products
Kazakhstan and Belarus	Placed a temporary ban on import of dairy products from New Zealand
Vietnam	Ordered an immediate recall on imported products from Fonterra and halt of circulation of milk powder manufactured by Fonterra
Singapore and Malaysia	Ordered an immediate recall on imported products from Fonterra
South Korea and Saudi Arabia	Immediate recall and required more levels of microbial testing on some of products
Companies	
Nutricia New Zealand Ltd	Recalled batches of two Karicare infant formulas sold in New Zealand
Coca-Cola China	Quarantined a 10,560-pound shipment of whey protein, though some of the products was used in batches of Minute Maid Pulpy Milk, which Coca-Cola maintains is safe
Danone Dumex (Malaysia)	Recalled batches of four of its infant formulas

Public awareness and the change of consumption

Consumer surveys were conducted to evaluate the public awareness of such incident and the change of consumption pattern for selected products at the time of scandal and after non-contamination announcement took place (Figure 2).

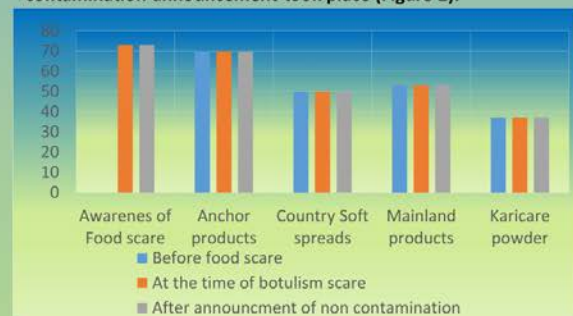


Figure 2. Public survey about products containing Fonterra's ingredients that were involved in botulism food scare in New Zealand.

